TR S-1 PSYCHOLOGICAL RESEARCH IN NATIONAL DEFENSE TODAY-1967

Technical Report S-1

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June 1967

U. S. Army
Behavioral Science Research Laboratory

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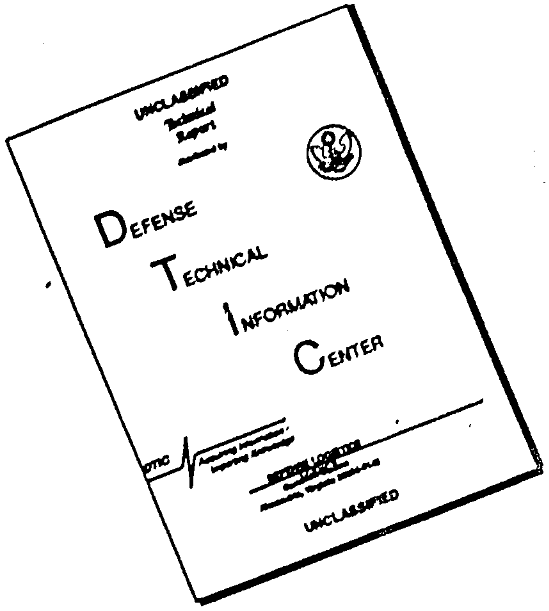

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Technical Report S-1

PSYCHOLOGICAL RESEARCH IN NATIONAL DEFENSE TODAY

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JUNE 1967

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PREFACE

This collection of technical papers which constitutes this report deals with research in the field of military psychology. The papers were presented at sessions of the program of the Division of Military Psychology at the 1964 Convention of the American Psychological Association in Los Angeles, California, September 1964. Sessions were planned and organized by the Editor at the request of the Division's Program Committee. The publication was undertaken at the request of the 1965 officers--Dr. Meredith P. Crawford, President, Dr. Richard Trumbull, President-Elect, and Dr. Saul B. Sells, Secretary-Treasurer.

The purpose of the 1964 program of the Division was to present an overview of research conducted by the Army, the Navy, the Air Force, and their contractors in the field of military psychology and related human factor disciplines. While the collection of papers presented does not constitute a comprehensive treatment of the subject, it is the Editor's hope that the substantial research accomplishments represented may instigate further thinking and experimentation on problems which have heretofore proved impervious to research attack or on which progress in research seems to have reached a plateau.

Sessions were designed to be representative of the research programs of the Department of Defense and of specialized agencies serving the separate services. The effort was in every sense a concerted one. The principal participants, each a specialist in his field, were invited by Dr. Uhlaner to collaborate with each other and to solicit participation from research scientists in other services and agencies. In turn, individuals selected by the principal participants were in good position to review specified areas of activity in terms of the state-of-the-art and anticipated developments in military psychology.

For the present publication, the sessions of the program are designated Parts I through X. The individual presentations constitute the chapters within each Part, with the exception of Parts IV, V and VII, for which the participants have presented their contributions as an integrated discussion. References have been placed at the conclusion of each chapter or part as appropriate.

The Editor expresses his appreciation to the many individuals who have made a contribution to this publication. Dr. Charles W. Bray, Dr. Charles W. Hill, and Dr. Arthur J. Drucker, members of the 1964 Program Committee of the Division of Military Psychology of the American Psychological Association, gave freely of their time and talents in laying the groundwork for the program which resulted in this publication. Dr. John T. Dailey, President; Dr. Meredith P. Crawford, President-Elect;

and Dr. Saul B. Sells, Secretary-Treasurer--officers of the Division of Military Psychology during 1964--provided guidance in administrative and programming matters. If the sessions moved forward with a measure of liveliness and fluidity, it was due in great part to the ingenuity and resourcefulness of Dr. Drucker who was of great assistance to the Editor in this phase of the undertaking as well as in the continuing efforts leading to the final publication itself.

Special recognition is accorded the invited principal participants who planned, organized, and chaired the sessions. We express our appreciation also to authors of individual contributions.

As always in an undertaking of this kind, the list of persons who have contributed in unacknowledged ways is long. The following acknowledgements are gratefully made to members of the staff of the U. S. Army Behavioral Science Research Laboratory: to Miss Emma Brown who in performing the duties of technical editor contributed order and continuity to the publication as a whole; and to Miss Lois Northcott, who gave indispensable support in maintaining the flow of communications between Chairman-Editor and participants and in keeping program arrangements under control.

J. E. UHLANER
Chairman, 1964
Program Committee, Military Psychology Division
American Psychological Association

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PSYCHOLOGICAL RESEARCH

IN NATIONAL DEFENSE

TODAY

CHAPTER 1

J. E. UHLANER

TODAY'S APPROACHES TO MILITARY PSYCHOLOGICAL RESEARCH

The subject is military man--military man in the higher reaches of space, in the depths of the sea, military man as commander, information processor, decision maker, using powerful weapons systems, intricate communications networks, even the techniques of diplomacy, working alone or as a member of a small or large team.

Man embedded in these military systems is the concern of military psychologists. Their approaches are influenced by civilian industrial development, social progress, growth in basic knowledge, and requirements for inter-nation and inter-peoples communication. The problems of military psychology are classically the problems of applied psychology and applied research psychology. Today, more and more, they are also the problems of the behavioral sciences, operations research, and perhaps even of science in general.

Fundamental to science is the use of objective measures and careful observation in place of assertion and dogma for the purpose of "accepting" or rejecting hypothesis. In applied research, and especially in problems where man is a key variable, an appropriate criterion or measure of performance effectiveness is the underpinning of the research base for problem areas designed to yield results translatable into effective military command decisions and successful mission accomplishment. Research scientists have become increasingly aware of the necessity of extending the concept of evaluation to a vast complex of activities. The classical criterion, however carefully defined, is typically a fraction of performance. It is a valuable research tool when relative measurement suffices, and when a single aspect of the "personnel sub-system" is of interest, but such a criterion does not suffice for the modern military user. It is the "mission accomplished" impact the military user is after, and it is this impact that the total systems criterion must reflect, considering a fuller range of the personnel sub-system variables and their interaction.

The research scientist or military psychologist of today more and more views man in this newly defined setting. Recognizing that to military management the salient concern is effective mission output, the researcher no longer can afford to ask simply: Is man A better than man B? Is training program A better than training program B? Is console A better than console B. Rather, he must ask: Do the end products of the developed man-weapon system meet the user's requirements in terms of specified percentages of accuracy, completeness, and rate of output for a given cost? Given

a specified quality of personnel, specified amount and type of training of these personnel, specified work methods, and specified interface with their equipment, is the probability that Company A can take a specific parcel of terrain a sufficient basis on which the commander can make an effective decision? As human factors research moves toward these more sophisticated evaluations, efforts such as these, which we might call "manned-systems research," will undoubtedly accelerate and these efforts will have more meaning for military management.

Manned-systems research approaches build on techniques and knowledge derived from the classical fractions of military psychology--personnel research, selection research, training research, human engineering, human factors engineering, and many other research programs which have not attained organized structure or standardized terminology. Such special research programs would include, for example, work methods research, fatigue studies, studies of environmental effects, organization behavior, military group dynamics, optimization modeling, and cost effectiveness. Moreover, each of the above special programs frequently moves in methodology and approaches toward this newer, more integrated effort, here called manned systems research.

Just to take one of the special programs as an example, whereas the human engineer was almost solely concerned with improvement of the specific machine in the system and primarily backed up the design engineer in producing hardware which is more efficient and more compatible with the human element in the system, his recent concern with all other aspects of the personnel subsystem is indicative of the above trend. He, like the selection researcher, training researcher, and in fact all other military research psychologists, is becoming more and more concerned with the total man-machine output. The manned systems research scientist attempts to measure the total effectiveness of the system.

A contrast of the more classical human engineering approach with today's thinking in a specific systems setting highlights the above point. In the system involving the extraction of information from photographs, it is customary to use a stereoscope as a specific piece of equipment for the job of interpreting. The classical human engineering scientist would have been concerned with providing the design engineer with a basis for improving the stereoscope used in image interpretation, making its mechanical characteristics compatible with the characteristics of the image interpreter. The manned-systems researcher, on the other hand, would determine--by measuring output with stereoviewing and without--whether stereoviewing enhanced the accuracy and completeness of the information produced sufficiently to make the instrumentation worthwhile. Further, he would make his recommendation to the manager responsible for developing the total system rather than to the design engineer responsible for building the stereoscope.

Moreover, in manned-systems research, the objective is to measure and interrelate a variety of human factors variables including individual differences, selection-assignment specifications, type of training, work methods, special equipment, and computer considerations. Determining these interrelationships and use of mission output as the criterion in measuring job performance and systems effectiveness constitutes the goal of the military research psychologist concerned with broader and more significant support of the military managers today. Research is hopefully proceeding toward the ultimate capability of presenting, on a cost basis, measures of the accuracy, completeness and

timeliness of systems output to be expected with a

given group of individuals, subjected to a
given course of training, using
given work methods, supplied with
given special aids and equipment,

for a specified military setting, all of the foregoing taken as a set in the mathematical sense. The impact of these variables needs to be studied with respect to the output of a particular manned system and then generalized. Emphasis here is on the end product--the effective execution of a mission. The aim is to avoid sub-optimization. Each functional aspect is related to total system performance.

One of the hallmarks of manned-systems research is simulation. Because of the speed of change accompanying a proliferation of scientific developments, systems under development are often obsolescent before they are completed. Add to these pressures the cost of prolonged complex development. The military psychologist is hence challenged by multiple pressures to reduce lead time. This challenge may be partly met by the sophisticated use of simulation, often with the aid of computers. Such effort requires extensive interaction with other scientists in order to work on concurrent schedules, and calls for the determined search for general principles derived from human performance experimentation which would be applicable to whole families of systems to follow. The military research psychologist has been thrust into the role of helping to develop these complex modern man-weapons systems. It is within this general area that the psychologist's role as researcher may blend with his role as developer.

For his part in developing these systems, the military psychologist is asked to assist in establishing the appropriate breakdown of functions to be performed--the jobs of individuals or of teams within the system. He is asked to project the kinds of individuals needed. He is asked to establish interrelationships and hierarchies within the system, to look at equipment and help engineers so design it as to make functions and jobs easier and to tailor them within the capability of the men available. Concurrently, he is asked to develop programs, devices, aids which will train each individual and the teams to perform the functions required. He is asked to look at the activities performed by individuals to see whether he can improve work methods. In practice, all the processes in the development of a system may be recycled many times, a contingency which makes human factors research and applications dynamic and often tentative at this stage of behavioral science knowledge.

How do we move toward a more integrated application of behavioral science to the new and expanded interrelationships of men and machines in the military effort. In the forefront is the need for effective means of testing the value of innovations in a system and changeovers from one system or subsystem to another. Here, the development of reliable, quantifiable--and practicable—measures of systems output is pertinent. In manned systems evaluation, it is true, many not unfamiliar measurement requirements are encountered. But also encountered are methodological limitations. For example, the reliability and criterion consistency of the effectiveness measure in the systems context present unique difficulties--difficulties which the classical military psychologist has not had to face. The difficulty of replication depends upon the extent to which the entire system must be involved. Individuals participating in the experimentation become practiced, and hence can no longer serve as subjects

for replication; equal but unpracticed groups of individuals may be difficult to obtain. Simulation used for evaluation of a system must deal with all relevant inputs into the system. The researcher must deal with the relative values the user places on various outputs. It is, in fact, not uncommon for the simulation exercise to be even more realistic than an actual operation in that simulation strives to reproduce a rich and complex environment encompassing all the significant activities of many actual situations, even to the point of anticipating contingencies which could not by chance occur simultaneously in one real stiuation.

I have singled out systems research as one of the newer developments in the field of military psychology. Its value lies in its manifest responsiveness to the mission-oriented military user.

Recognizing the extreme costliness of the above approach, and the compelling need for sub-optimization from time to time, many military problems of commanding importance should continue to be attacked from the more classical point of view--initial screening, manpower procurement and allocation, training, human engineering. The nation's military organizations must induct large numbers of men from the civilian manpower pool to perform an enormous variety of jobs, sorting out the grossly usable from the unusable. Training must be provided in a short period of time to prepare large numbers of civilian-oriented young citizens for transition to soldiers, sailors, or airmen, and to impart individual and team skills. Military commanders must find ways of motivating these men under diverse conditions. Promotion systems in our society must be based on valid evaluation as one cornerstone of an effective incentive program. In all these requirements, the common focus is on the individual, his assessment and his effective utilization as a member of the Armed Forces.

Continuous programs of research to meet these and many other important requirements are essential in providing the United States with an efficient military force having high morale and combat readiness capability. It is in such areas of endeavor that classical military research psychology plays and will continue to play a most vital role side by side with the newer manned-systems military research psychology.

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PART I

SCREENING AND CLASSIFICATION

INTRODUCTION TO PART I

Part I presents an overview of the status and direction of research conducted by the Army, the Navy, and the Air Force to develop methods of screening young men for enlistment or induction, classifying enlisted men for various job assignment areas, and selecting potential commissioned and noncommissioned officers.

Under the current military procurement structure, screening is the process of selecting from a pool the usable or the most usable individuals for a given program of training or utilization. The concept is one of accept or reject--in other words, of pass-fail. Research is concerned with measuring the most relevant characteristics of individuals in the pool and identifying the most appropriate cut-off scores to achieve the pass-fail dichotomy.

Classification in the military services is the process of relating the abilities of a set of accepted individuals to the demands of a set of jobs to be filled. The basic concept here is the matching of individuals with assignments so as to maximize total performance. We are concerned not only with characteristics relevant to the various assignments, but also with differential relevance to different assignments.

Since these are operational problems, some discussion of the operational programs is useful in providing the setting for a discussion of the status of research conducted within and throughout the military services. Each of the chapters in Part I extends to the research activities and management policies of all the military services in dealing with selection and classification problems.

As principal participant, Mr. Edmund F. Fuchs, Chief of the Military Selection Research Division of the U. S. Army Behavioral Science Research Laboratory, was responsible for inviting participants and for organizing topical coverage of the area. Mr. Fuchs is the author of Chapter 2 in which he presents the strategies of the services in selecting enlisted personnel and the rationale and research basis for the psychological instruments by which the strategies are implemented. He concludes with a brief account of the direction of current research efforts.

In Chapter 3, Dr. Victor Fields of the Personnel Research Division, Bureau of Naval Personnel, concentrates on differential classification and the optimal allocation of enlisted personnel to training and jobs. He presents the approaches of each of the Armed Services to the problem of optimal allocation and the impact of these approaches on research toward greater effectiveness of classification instruments and procedures. He concludes with a projection of the potentialities of computerized techniques for attaining a more efficient differential classification procedure and applying it more efficiently.

Chapter 4, an account of the use of noncognitive measures in the selection of officer personnel, was prepared by Dr. Leland D. Brokaw of the Selection and Classification Division, Personnel Research Laboratory, U. S. Air Force, San Antonio, Texas. He discusses some successful and some unsuccessful approaches to the identification of potential officers as the take-off point for current and planned research, including continued evaluation of peer ratings as predictors of officer performance, the Army's on-going exercise in the differential classification of commissioned officers by major areas of assignment, and the evaluation of school factors in leader selection.

CHAPTER 2

EDMUND F. FUCHS

SCREENING POTENTIAL ENLISTED MEN

Psychological research in the military services has its longest history in the contributions it has made to the methods by which men are screened for service and classified for jobs within the services. This history goes back to the Army Alpha and Beta examinations of World War I, reported by Robert M. Yerkes (1929). Between World War I and World War II, no further attempts were made to develop psychological screening instruments for military use. The effort was renewed in 1940, however, with the development of early forms of the Army General Classification Test during the draft build-up prior to World War II--development which continued and expanded during the period of hostilities (Staff, Personnel Research Section, 1947).

In the period since World War II, all the military services have wrestled with the problem of obtaining adequate numbers of enlisted personnel with the mental abilities needed to assimilate training for military jobs. For the most part, more qualified men are needed than would become available through a passive program of evaluating young men who choose to seek out a recruiting office. In this connection, a study prepared by John T. Dailey (1957) while he was with the Navy Department suggested that a relatively constant proportion of young men of suitable age are interested in joining a service. The difficulty arises from the fact that the proportion is much too small to meet present requirements and the core of natural volunteers includes many who do not measure up to the mental standards required for effective enlisted service. On the other hand, one factor has served to increase significantly the proportion of young men volunteering for enlistment since 1950--the draft. The probability of involuntary induction undoubtedly serves to push many young men into voluntarily enlisting in one of the services--young men who would not enlist if there were no selective service law.

The basic situation is thus confounded by cross-currents. Clearly, aggressive recruiting efforts and effective screening measures are required. Aggressive recruiting is needed to develop a selection ratio with more candidates than the number of men needed for training. With a relatively tight selection ratio, effective screening measures are needed so that on the one hand potentially good men are not rejected, while on the other hand potentially poor men are not accepted to waste training and processing costs and manpower spaces. Research to develop such measures deals with problems of numerical requirements and the varying enlistment standards of the Army, the Navy, and the Air Force.

MANPOWER REQUIREMENTS OF THE SERVICES

The problem of how many recruits are needed each year has great bearing on the selection ratio and thereby on the screening program. We note that a number of recent studies focus on "force structure". In this context, the term relates to the distribution of personnel by length of service (G. C. Smith, 1964).

The major concern here is with enlisted men in their first term of service as against careerists, or those who have reenlisted at least once. The "force structure" concept attempts to determine relative costs of first-termers vs. careerists against their relative outputs. The average costs of maintaining an enlisted man, to include not only direct pay but also costs for housing, feeding, training, medical care, dependents, and ultimately a share in his retirement are considered for individuals who serve only one tour as against those who become careerists. Average costs for careerists are higher, since almost all these factors tend to increase with length of service. On the other side of the ledger is the question of the number of months of effective service which can be expected from individuals in various enlisted categories. For this purpose, the length of tour must be reduced by training time, leave time, and the like. (One factor here is that the inductee's tour is only two years as against three years for the regular Army recruit, and four years for most Navy and Air Force recruits.) Careerists obviously provide a greater average number of months of effective service than do first-termers. Hence, the length of time required to bring an enlisted man up to effective performance in the job is the critical variable. A corollary is the extent to which additional experience is reflected in better job performance. For this reason, enlisted jobs which need to be performed in a service are categorized according to the amount of training and experience needed for effective performance. This type of study usually suggests that careerists are needed in the leadership and advanced technical enlisted jobs, but that the bulk of basic enlisted positions can be more economically filled by men who serve only one or two tours of duty. However, even for these basic positions, there are significant gains in a four-year tour over a three-year tour and in a three-year tour over a two-year tour.

To return to the screening problem, the systems for obtaining the requisite numbers and caliber of enlisted personnel have evolved to meet the differing requirements of the services. One differential factor across the services has been the fact that for the last ten years only the Army has utilized the draft machinery--in addition to its voluntary recruitment program--to obtain enlisted personnel. The Navy, Air Force, and Marine Corps have relied exclusively on voluntary enlistments (although these have been aided by the spectre of the draft in the background to encourage young men to volunteer).

THE ARMY'S MENTAL SCREENING PROGRAM

ENLISTEES

We might well look at each service's screening techniques separately. The Army's experience with the problem of providing sufficient numbers of qualified enlisted men has resulted in a mixture of programs. These have seen the evolution from a personnel program in which screening was accomplished with one general ability test to a system in which differential classification type information is obtained as part of a screening process. The screening test is the Armed Forces Qualification Test (AFQT) which is still in use as a first screen. The classification type measures are seven aptitude area scores derived from the Army Qualification Battery (AQB). The AQB is a set of short tests paralleling those in the Army Classification Battery (ACB)--with the exception of the Radio Code Aptitude Test--but with a low ceiling. (The ACB and aptitude areas are described by Victor Fields in Chapter 3.) The AQB meets the requirement of indicating whether individuals meet minimum qualifications for various Army occupational training programs, but the battery is too short to provide effective classification information for most individuals.

The AFQT is an instrument developed jointly by all the military services and used by them for both enlistment and induction. It contains vocabulary, arithmetic reasoning, tool usage, and spatial relations items. It contains 100 questions, requires about one hour to administer, and yields scores which are converted to a percential scale standardized to the World War II reference population (Bayroff, 1963). Studies of various forms of this test have shown AFQT scores to be moderately related to performance in basic training (Bayroff, Seeley, and Anderson, 1960), rather highly related to performance in occupational training programs in the services though not so highly as the appropriate classification measures (Brokaw, 1959a), and moderately related to disciplinary record, that is, whether or not the enlisted man will complete his first tour with an honorable discharge and without a court-martial conviction (Klieger, Dubuisson, and Sargent, 1962).

The AQB was constructed to parallel the ACB, though without the more difficult items. It has also been shown to match the correlational patterns of counterpart ACB tests (Seeley and Anderson, 1963). Thus, the AQB aptitude areas can be considered to share the validity demonstrated for the ACB aptitude areas, which tend to run about .60 against training performance (with range from about .50 to about .85) (Helme and Fitch, 1962) and about .40 against rated job performance (Helme, Denton, and Bivins, 1963).

The Army program for screening applicants for voluntary enlistment has several aspects. The basic mental requirement for enlistment is a percentile score of 31 or higher on AFQT. A high school graduate who achieves a percentile score between 21 and 30 on AFQT is acceptable if he achieves Army standard scores of 90 or higher on at least three

aptitude areas derived from AQB measures. However, most men who voluntarily enlist in the Army are able to qualify for special inducements in the form of assurance of training in a desired occupational area or initial assignment to a particular overseas command. To qualify for such an enlisted commitment, the applicant must not only score 31 or higher on AFQT, but must also take the AQB and achieve an Army standard score of 100 or higher on the aptitude area related to the desired occupational area and 90 or higher on at least two additional aptitude areas.

Two current Army research efforts bearing on the problem of effective screening of enlisted personnel should be mentioned. One is the attempt to find a measure of interests, attitudes, and the like which will predict the extent to which an individual will use his abilities in the Army. Such a measure would add the "will do" evaluation to that of "can do" provided by the AFQT and AQB. The other research effort looks to a different mode of test presentation and response. This would involve use of a machine to present questions according to a program which would vary with whether previous answers were correct or not. Success in this effort may well let us get away from presentation of the same set of questions to all examinees, and perhaps let us find more efficient techniques.

INDUCTEES

The Army has used the draft to meet the portion of its requirement for enlisted personnel which it did not meet through voluntary enlistment. The Army programs have varied to meet the relative impact of the inductee input on its overall processing. While an average over several years shows approximately 45% inductee vs. 55% voluntary enlistee input to the Army, these proportions have varied widely from a period early in 1961 when 80% of the accessions were voluntary enlistments to periods during the Berlin incident when more like 60% of the accessions were inductees. Since the screening standards for induction are set by the Congressional legislation and supplementary Presidential and Secretary of Defense directives, they are relatively difficult to change.

The main mental screening for induction is accomplished by the AFQT, which is given first. Selective Service registrants who score at the 31st percentile or higher on the AFQT are considered acceptable as far as mental standards are concerned. Those who score below the 10th percentile are rejected (these are "permanently" rejected, receiving 4F Selective Service classification). The group scoring between the 10th and 30th percentile are then given the AQB. Those who achieve the equivalent of 21st percentile or higher on the General Technical (GT) Aptitude Area (a combination of verbal and arithmetic reasoning scores) and the equivalent of the 31st percentile or higher on two or more other aptitude areas are considered acceptable. Those not meeting these standards are rejected. But these men are rejected only so long as

standards are not lowered; they receive Selective Service classification 1Y if otherwise acceptable. Recent experience data indicate that, using the AQB screen, about half this AFQT group (10th to 30th percentile) are accepted.

The rejection of those in percentiles 0 through 9 on the AFQT is provided for in the law authorizing the draft. This standard reflects World War II experience of considerable difficulty in training or utilizing these very low mental level individuals. The group in question would be counterpart to those below Army standard score 65 on the AGCT of World War II. The supplementary screening of men who score from 10 to 30 on AFQT (called Category IV) reflects the results of Army studies with the Army Classification Battery. Men with aptitude area scores of 90 or higher on the Army standard score scale (equivalent to 31st percentile or higher) have tended to be able to pass a related training program and perform acceptably on the job. Two such aptitude area scores are required in order to make provision for variation in the jobs available at any one time and for the need to retrain men when unit missions are changed or appropriate jobs are otherwise not available. The General Technical Aptitude Area requirement for an Army standard score of 80 or higher (equivalent to the 21st percentile) reflects a recent study of Category IV personnel. This study suggested that such individuals who are also low on the GT Aptitude Area are handicapped in performing up to the level otherwise suggested by their other aptitude area scores.

With appropriate personnel and computer facilities available at the 70 or so Armed Forces Examining Stations (AFES), a more effective prediction formula could be provided by taking all the test scores into account. However, the current system of using AFQT, supplemented by AQB scores for Category IV personnel, seems to be reasonably effective while giving rise to few difficulties in operational implementation.

I recognize that the induction screening program is a joint activity of all the services. But in practive inductees enter the Army only, and the supplementary screening of Category IV men uses only Army measures. I have therefore discussed the screening of inductees as part of the Army's program.

THE NAVY'S MENTAL SCREENING PROGRAM

The Navy, like the Air Force and Marine Corps, depends solely on voluntary enlistments for its enlisted personnel procurement. The Navy procurement strategy has been the one most clearly in the classical selection and classification model. Although a short general test has been used at the recruiting station to indicate likelihood that an applicant could meet the prescribed standard (A. N. Smith and Guttman, I., 1961), the Navy has used the AFQT administered at the AFES as its primary mental screening test. The Basic Test Battery administered at the

beginning of boot training provides classification information on which to base allocation to specific job training programs. The Navy and Air Force attempt to accept as few applicants who score below the 31st percentile on AFQT as possible. However, supply and demand factors enter the picture quite markedly. Navy quotas tend to be only slightly affected by seasonal variation, whereas the caliber of personnel available as applicants is considerably higher during the months following the close of the school year and is noticeably lower early in the calendar year. Fairly recently, the Navy has provided a set of short classification-type tests to its recruiting activities as a counterpart to the new classification battery. These tests are used to evaluate applicants who are considered for enlistment against special training requirements. As with the Army's AQB, the validity of these short Navy tests is considered to be that demonstrated for the longer classification tests. The Navy's current research efforts on the procurement problem are generally in the direction of providing multiple forms of the short recruiting tests. Since the following chapter covers classification measures, I will not discuss these here.

Although the Marine Corps is in the Navy Department, its problems tend to be more like those of the Army. This similarity is reflected in the Marine Corps enlisted screening program, in which the AFQT and the Army's AQB are used in a fashion akin to the Army's screening of applicants for voluntary enlistment.

THE AIR FORCE PROGRAM

The Air Force system for procurement of enlisted personnel follows the industrial model, in contrast to the screening and classification sequence of the other services. The Air Force system projects position requirements and then enlists personnel with specific aptitude for training to fill those requirements. The AFQT is used with a relatively low cutting score. Air Force studies of the validity of the AFQT for predicting performance in job training courses in the Air Force showed very favorable results, with validity coefficients generally in the .50's (Brokaw, 1959a). However, the major screening operation for the Air Force is accomplished in a preliminary phase before the applicant is sent to the AFES to take the AFQT. Special testing teams provide frequent scheduled testing sessions at different cities and towns in their area. The test battery is called the Airman Qualifying Examination (AQE). It is a relatively short version of the former Airman Classification Battery, cut down to about 2½ hours of testing. Unlike the other services, the Air Force has transferred its primary classification testing to this procurement point. Only special purpose tests are given during orientation training for those accepted. Of course, tests are available at the various air bases for reclassification purposes. The AQE provides scores in four aptitude areas--General, Electronics, Administrative, and Mechanical. A percentile scale similar to that used with the AFQT is used for the aptitude indexes, as the scores are called. The recruiting stations are notified periodically of the quotas needed

to fill projected training requirements. With these quotas and minimum percentile scores on the aptitude areas required to qualify for training, recruiters arrange for testing the applicants and then see which applicants qualify for the training spaces in the quotas. Since most Air Force training programs require minimum scores at the 40, 50, or 60 percentile levels in the relevant aptitude areas, the qualitative requirements are relatively high, and only borderline cases are really screened on the AFQT at the AFES. As with the Army's AQB, the validity of the AQE has been demonstrated primarily with the longer Airman Classification Battery. Validity is again very high, running .60 to .80 against training and somewhat lower against on-job performance (Brokaw, 1959b).

The Air Force is seeking improvements in its procurement system through research efforts to develop self-description measures to screen out individuals with personality problems. The failure rate for high school graduates who qualify on the aptitude indexes is very low. Hence, the main target for these measures would be applicants who have not finished high school. This group contributes too high a proportion of washouts, even after screening on the aptitude indexes (Gordon and Bottenberg, 1962; McReynolds, 1964).

SUMMARY

In summary, we have a picture of a complex screening program in response to a complex personnel procurement problem. On the one side of the picture, we have a 31st percentile score on AFQT, representing a desirable global aptitude standard. On the other side, we see differential classification measures used extensively in the screening program, with applied standards based on aptitude qualifications for available military job training programs. A main concern of current research in this area is to develop effective self-description measures to screen out men who do not possess enough self-discipline and other characteristics for success in military service.

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VICTOR FIELDS

DIFFERENTIAL CLASSIFICATION AND OPTIMAL ALLOCATION OF PERSONNEL IN THE MILITARY SERVICES

The volunteers and potential inductees for military service with which Chapter 2 was concerned are civilians on the threshold of military service. Chapter 3 is concerned with persons who have already been screened and who have entered the military service. Their abilities need to be assessed more precisely than in the screening process so as to provide the data by which differential classification and assignment in the military service may be accomplished.

The research programs of the services are similar to the extent that each aims to improve the efficiency of personnel assignment and utilization through better classification and allocation of personnel. Differences in the basic mission and job structure of the three services, together with differences in their administrative approaches, are the distinguishing features of their classification programs.

The present chapter describes in general terms 1) the current classification batteries and methods of personnel assignment in the three services, 2) recent or current research representative of efforts to improve these methods, and 3) the impact of computers on differential classification.

CURRENT CLASSIFICATION BATTERIES

The classification batteries of the respective services have undergone varying degrees of change over the last decade. A brief description of the current classification batteries of the three services is therefore presented for background information. Basic features are summarized in Table 1.

Table 1

FEATURES OF CLASSIFICATION BATTERIES OF THE ARMED SERVICES
AS OF SEPTEMBER 1964

	No. of Tests	No. of Aptitude Combinations	Mean	Standard Deviation	Administration Time (Hrs.)
Air Force	10	4	47.5	28.8	2
Army	11	8	100	20	4
Navy	9	6	50	10	$3\frac{1}{2}$ - $5\frac{1}{2}$

U. S. AIR FORCE CLASSIFICATION INSTRUMENTS

The Airman Classification Battery. Lecznar and Davydiuk (1960) have summarized the evolution of Air Force classification testing from 1948 to 1960. In 1948, the first Air Force classification battery for enlisted men (Airman Classification Battery AC-1A) consisted of 12 tests and six Biographical Inventory keys. In 1949, it was superseded by Form AC-1B which contained 13 tests and 7 Biographical Inventory keys. Except for minor changes, the latter instrument was used until 1956 as a basis for centralized classification of enlisted personnel using eight aptitude indexes. In 1956, the Airman Classification Battery AC-2A, reflecting several major changes, was promulgated. One major change was a different grouping of Air Force jobs. As a result, the battery yielded five aptitude indexes based on scores from 15 tests, plus scores on three scales of a Biographical Inventory. A second major change was in the score metric. A modified percentile score providing 20 scale units was established for the composite scores. This battery required about five hours and 30 minutes of testing time exclusive of breaks between tests.

The Airman Qualifying Examination. In 1958, the Air Force instituted systematic pre-enlistment aptitude testing in the field followed by centralized classification testing. For this purpose, the Airman Qualifying Examination, a short version of the Airman Classification Battery, was used. Finally, in 1959, the Airman Qualifying Examination, administered in the field, became the sole basis for both screening and classification of new enlistees; the longer Airman Classification Battery was discontinued. The Airman Qualifying Examination-62 is the current battery (McReynolds, 1964). It consists of ten tests which yield, by various test combinations, four composites or aptitude indexes: Mechanical (M), Administrative (A), General (G), and Electronic (E). Total testing time excluding breaks is about two hours.

The composition of the Airman Qualifying Examination-62 and the corresponding aptitude indexes is shown in Table 2. An aptitude index is formed by combinations of three to four tests. Some tests enter into the composition of more than one index. In contrast to the old Air Force stanine, the present battery is based on a 20-point percentile scale ranging from a minimum score of 1 to a maximum of 95. The Airman Qualifying Examination was standardized to a mean aptitude index of 47.5 and a standard deviation of 28.8.

Table 2

AIRMAN QUALIFYING EXAMINATION TESTS AND APTITUDE INDEXES

	Title of Test	No. of Items	M	A	G	E
1.	Airman Arithmetic	45		x		
2.	Arithmetic Reasoning	15		x	x	x
3.	Word Knowledge	30		x	x	
4.	Mechanical Principles	15	x			
5.	General Mechanics	15	x			
6.	Tool Functions	15	x			
7.	Hidden Figures	15	x		x	
8.	Electrical Information	15				x
9.	Pattern Comprehension	16				x
10.	Technical Data Interpretation	10				x

Many of the recent changes in the content and administration of the Air Force classification battery were apparently dictated by administrative considerations. The most important consideration appears to have been a need for selective recruiting, that is, recruiting for specific job categories. As a result, the Air Force discontinued the conventional two-step practice of screening in the field on the AFQT and subsequently classifying acceptees in a centralized location. Instead, the Air Force now follows the practice of simultaneously screening and classifying in the field at the point of recruitment and prior to administration of the AFQT, a practice reflected in a report on the Airman Qualifying Examination as a "selection-classification battery" (McReynolds, 1964).

These changes in test content and test administration procedures have produced noticeable gains. Total time for test administration has been reduced from over five hours to two hours. Administrative efficiency has been increased by combining prescreening with classification and by simplified scoring so that no negative weights are employed. According to Lecznar (1963), the mean aptitude index for recruits has risen from the 40-45th percentile in 1956 to the 52-62d percentile in 1961.

THE U. S. ARMY CLASSIFICATION BATTERY

The U. S. Army accomplishes initial classification of personnel for school training and for assignment to jobs by means of the Army Classification Battery, which currently consists of the eleven tests shown in Table 3. Total testing time for the battery exclusive of breaks is four hours.

Table 3

CURRENT ARMY CLASSIFICATION TESTS

Title of Test	Symbol	No. of Items
1. Verbal	VE	50
2. Arithmetic Reasoning	AR	40
3. Pattern Analysis	PA	49
4. Army Clerical Speed	ACS	110
5. Army Radio Code Aptitude	ARC	150
6. Shop Mechanics	SM	40
7. Automotive Information	AI	40
8. Electronics Information	ELI	40
9. Mechanical Aptitude	MA	45
10. Classification Inventory[a]	CI	125
11. General Information	GIT	50

[a]A self-description personality questionnaire used for classification to infantry combat jobs.

Since World War II, personnel research in the Army has sought improvement in techniques for classifying and assigning recruits. From a single general mental ability test in World War II, the Army has progressed to the current differential system of classification. In 1949, the Army adopted the Aptitude Area system of classification. In 1955, after a long period of development--and using some criteria based on actual combat performance--the Combat Aptitude Areas were included. More recently the Combat Aptitude Area was divided into two aptitude areas: Infantry (IN) and Armor-Artillery-Engineers (AE). There are currently eight aptitude areas which are shown with their corresponding test composites in Table 4. A given score in a prescribed aptitude area is prerequisite to assignment to an occupational area.

The Army score metric is a normalized scale with a mean of 100 and a standard deviation of 20.

Table 4

CURRENT ARMY APTITUDE AREAS AND CORRESPONDING TEST COMPOSITES

	Aptitude Area	Symbol	Test Composites
1.	Infantry	IN	(AR+2CI)/3
2.	Armor, Artillery, Engineers	AE	(GIT+AI)/2
3.	Electronic	EL	(MA+2ELI)/3
4.	General Maintenance	GM	(PA+2SM)/3
5.	Motor Maintenance	MM	(MA+2AI)/3
6.	Clerical	CL	(VE+ACS)/3
7.	General Technical	GT	(VE+AR)/2
8.	Radio Code	RC	(VE+2ARC)/3

A weighted composite of only two tests is used for each aptitude area, with some tests being used more than once. The Army aptitude areas represent occupational or job areas which have been clustered on the basis of similar aptitude requirements.

U. S. NAVY CLASSIFICATION BATTERY

Since World War II, the U. S. Navy has employed a battery of classification tests known as the Navy Basic Test Battery. The Basic Test Battery was so named because it was originally intended for administration to all recruits processed through the Recruit Training Center, while supplementary tests were to be administered only to candidates for certain occupational categories. For purposes of clarity, however, the term Navy battery will be used herein to encompass all the Navy tests used in the classification process.

Currently, the Navy classification battery contains nine tests which are used in various combinations to assign recruits to training in about 60 naval ratings or occupational fields. These ratings are roughly comparable to the Army Military Occupational Specialties (MOS) and the Air Force Specialty Codes (AFSC). From the inception of the Navy Classification Battery in World War II, the tests have been used in combinations which in effect form aptitude composites. The best combinations are determined by virtue of test correlation with performance in given schools. These combinations, however, have never been formally identified as composites, aptitude areas, or indexes. The score metric employed with all Navy classification tests since World War II is the Navy Standard Score, defined as a normalized scale with a mean of 50 and a standard deviation of 10. The tests of the Navy Classification Battery are shown in Table 5. Total testing time of the battery varies from approximately $3\frac{1}{2}$ hours to approximately 5 hours because not all recruits take all the tests of the battery. Tests such as the Electronics Technician Selection Test, Sonar

Pitch Memory Test, Radio Code Test, and Foreign Language Aptitude Test are administered to personnel who score above the mean on a combination of GCT plus ARI.

Table 5

U. S. NAVY CLASSIFICATION TESTS

	Title of Test	Symbol	No. of Items
1.	General Classification[a]	GCT	100
2.	Arithmetic	ARI	50
3.	Mechanical	MECH	100
4.	Clerical	CLER	210
5.	Shop Practices	SHOP	50
6.	Electronics Technician Selection	ETST	70
7.	Sonar Pitch Memory	SPMT	40
8.	Radio Code	RCT	150
9.	Foreign Language Aptitude	FLAT	59

[a]The title "General Classification Test" reflects a kind of administrative atavism. Its pre-World War II ancestor was correctly described by the title. Currently, the title (retained for administrative convenience) belies its content, which is exclusively verbal--sentence completion and verbal analogies.

The tests of the Navy Classification Battery are used in six different combinations of two to three tests which for convenience may be called aptitude composites as shown in Table 6.

Table 6

NAVY APTITUDE COMPOSITES

	Aptitude Composites	Test Combinations
1.	General Technical	GCT + ARI
2.	Electronics	ARI + 2(ETST)
3.	Mechanical and Electrical	GCT + MECH + SHOP
4.	Clerical	GCT + CLER
5.	Sonar	GCT + ARI and SPMT
6.	Radio	GCT + ARI and RCT

CURRENT AND RECENT RESEARCH ON DIFFERENTIAL CLASSIFICATION

Since World War II, the Army, Navy, and Air Force have been vigorously pursuing independent programs of research to improve the existing methods of differential classification and allocation of enlisted personnel. The aim of such research has been and continues to be to achieve greater efficiency in utilization of available talents among the recruits who have been enlisted or inducted.

Such research takes the form of validation of existing tests or combinations of tests against appropriate criteria of school or on-the-job performance. It also takes the form of experimental test development and validation to identify predictive variance not being measured by operational tests. The ultimate aim is to improve the differential validity of the battery.

In each of the three services[1], the battery of aptitude tests used in differential classification and assignment of personnel has undergone considerable evolution. The changes may be attributed to at least three causes: (1) continued refinement in test construction and test applications resulting from test research; (2) the technological revolution with consequent restructuring of jobs and training curricula--restructuring which has directly influenced the performance criteria employed in test validation; and (3) the increasing demands for technical skills associated with sophisticated man-machine systems which in turn have increased the demand for aptitudes of a high order.

Space does not permit a complete review of all the classification research recently reported and now under way in the military services. The studies described below are a sampling from recent research activities.

RESEARCH STUDIES

U. S. AIR FORCE

McReynolds (1963) has recently reported the validity of the Airman Qualifying Examination for predicting performance in 49 technical training courses. Final course grade in standard score form was used as the criterion. The training courses were categorized as mechanical, administrative, general, and electronics--corresponding to the four aptitude indexes with the same names. McReynolds summarized the results as follows:

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[1] The U. S. Marine Corps, while a component of the U. S. Navy, employs the classification tests of the U. S. Army.

> With only two exceptions, the selection aptitude index has the highest validity for the courses in its area and these values for the most part range from .55 to .70....the Electronics AI yields the most satisfactory overall level of prediction, but the other three indexes are also at acceptable levels. Thus, the Airman Qualifying Examination has proven its adequacy as an instrument for use in the initial assignment of enlistees to technical training schools.

In an Air Force study reported by Lecznar (1964), years of education as a possible predictor of technical training success was investigated. The results of the study showed that years of education as a continuous variable, when added to the classification test variables, yields no practical improvement in the prediction of training performance. However, Brokaw (1963) reports that prediction of technical school success improved significantly when a number of education variables derived from self-reports were combined with Air Force Aptitude Indexes.

Flyer (1963) studied the validity of Air Force aptitude indexes together with high school reference data and basic training evaluations as predictors of unsuitable adjustment. The latter two variables, school reference data and basic training evaluations, proved predictive of adjustment to Air Force standards of performance.

In a study comparing Air Force aptitude indexes with corresponding test composites of Project Talent tests (Lecznar and Tupes, 1963), conversion tables between the two measures were developed to provide a basis for standardizing future tests directly on a 1960 population in lieu of the World War II population on which present Air Force tests are standardized.

U. S. ARMY CLASSIFICATION RESEARCH

The Army conducts studies to maintain the Army Classification Battery and to increase its predictive and differential validities. A predictive validity study may concentrate on a single job area. The aptitude area composite which is used to assign men to a job area is compared with a second and sometimes a third composite selector. Evaluations of comparative validity determine whether a composite should be replaced. Both school and on-the-job criteria are employed to evaluate the composites. Results of individual predictive validity studies are combined and analyzed to yield a comprehensive assessment of the effectiveness of the Army battery for differential classification. The focus of inquiry is on the content and scope of each test. The principal aim, however, is to determine how each test should be modified to increase its usefulness in the battery for differential classification (Helme, 1960).

In a summary study of the differential validity of the ACB for 73 courses in seven job areas (electronics, electrical maintenance, precision maintenance, motor maintenance, clerical, general technical, and radio code), Helme (1960) found the Automotive Information, Army Clerical Speed, Army Radio Code Aptitude, and Electronics Information tests to be highly satisfactory selectors for differential classification. The Verbal Test, Pattern Analysis Test, and Arithmetic Reasoning Test were effective for some specific occupational areas but somewhat more useful across several areas than is desirable for differential classification. The Mechanical Aptitude Test and Shop Mechanics Test proved to be effective in assignment. The validity patterns of tests in the mechanical-electrical areas indicated a need for improvement in differential prediction.

In a subsequent study (Helme and Fitch, 1962), the relationships between Army classification tests and final course grade in 75 MOS were factor-analyzed to investigate the occupational groupings of Army jobs. The analysis yielded six factors which accounted for almost all the valid variance: a large general factor; two large group factors (electronic and mechanical), and three small group factors (clerical, motor mechanics, and radio code operations). The 75 MOS were classified into 10 groups according to their factor loadings. Standard regression equations for each cluster were derived. The results showed that the test combinations differentiated nine of the clusters. The test combinations and the job clusters corresponded very closely to the aptitude areas and occupational areas currently in use, demonstrating the effectiveness of the present system but indicating some basis for reconstituting the present aptitude areas.

U. S. NAVY CLASSIFICATION RESEARCH

The Navy classification research program has three aims: (1) to discover test content that will contribute unique valid variance to the existing battery, (2) to improve predictive validity of the existing battery by improvements in the component tests of the battery, and (3) to improve differential validity of the existing battery by reconstituting test combinations that are used to predict performance in schools.

In the most recent study to improve the differential validity of the Navy Classification Battery (Alf, Gordon, Rimland, and Swanson, 1962), the Naval Knowledge Test, the Biographical Information Blank, and the Navy Activities Preference Blank (an interest inventory) were added to the existing tests of the 1957 battery for experimental purposes. Tests with more than one section were part scored, resulting in an experimental battery of 25 predictors. The battery was administered to about 51,000 recruits assigned to over 80 Navy schools for training in various occupational fields. The measure of criterion performance was final school grades.

While the advantages of a unique set of predictors and weights for optimal assignment to each school were fully recognized, considerations of economy and practical limitations under current conditions of military classification precluded such an approach. For administrative feasibility in operational testing, a limited number of prediction equations based on groupings of similar courses was aimed at. Groupings were determined on the basis of (1) similarity in curriculum content, (2) similarity of interests as measured by the Navy interest questionnaire, (3) patterns of validity, and (4) results of a factor analysis of predicted grades derived from actual regression equations. The analysis led to the identification of four occupational groupings: clerical, electronic, electrical-mechanical, and general technical.

This study resulted in the following major findings:

1. The Naval Knowledge Test which was presumed to measure some kind of motivation for Naval activities did not add any significant variance not already accounted for by other tests in the battery. It was therefore not included in the final composition of the revised battery.

2. The Biographical Information Blank showed very little independent validity and was therefore not included in the revised battery.

3. The Arithmetic Computation section of the Arithmetic Test tended to depress the validity of the test. The computation section was therefore removed, leaving only arithmetic reasoning items.

4. The Clerical Test was found to contribute some unique valid variance to the battery but not enough to make it a very effective test. Nevertheless, this test was retained in the battery with the expectation of further effort to increase its validity.

5. The Shop Practice section of the Electronics Technician Selection Test proved to be highly valid for prediction of grades in the mechanical and electrical schools. The section was therefore considerably lengthened, removed from the Electronics Technician Selection Test, and made into a separate test of the battery.

6. The median intercorrelation among test combinations or composites was reduced from .80 to .70, thereby increasing the differential validity of the total battery.

7. The changes in the composition of the battery yielded an increase of approximately 5% in the number of recruits eligible for assignment to schools without any loss of validity.

8. The Navy Activities Preference Blank did not prove to be a useful addition to any of the test composites. As an adjunct to the battery, however, scores on the several keys of the blank serve as guides to the classification interviewers in determining level of the recruit's interests or aversions with respect to certain occupational fields.

In another study (Shaycoft, Neyman, and Dailey, 1962), tests of the Navy battery and Project Talent tests were administered to Navy recruits. Results were compared with Project Talent data on male high school students. The intercorrelations among these tests will provide useful data in the event it is desired to use a more recent standardization population than the World War II standardization population on which the present battery is based.

In an effort to discover additional valid variance, three tests--Automotive Knowledge, Dial and Table Reading, Pattern Comprehension--have been developed. These tests have been validated against school performance criteria. Based on their validity for performance in certain schools and their intercorrelations with tests of the Navy Classification Battery, they show promise of contributing to the predictive efficiency of the battery.

THE IMPACT OF COMPUTER TECHNOLOGY ON DIFFERENTIAL CLASSIFICATION

A review of the published literature on military classification research indicates no spectacular breakthroughs in the way tests are used singly or in combination to predict performance. The literature indicates an almost exclusive use of school grades as criterion measures. The implicit assumption is that performance in training schools is correlated with performance on the job, although this relationship for all schools and all job areas is open to serious question (Glickman and Kipnis, 1960). Cutting scores for assignment to schools are tantamount to standards for assignment to occupational fields. Allocation of personnel on the basis of cutting scores on test composites, aptitude areas, or aptitude indexes are performed by accounting machine procedures and punched cards. These procedures can exploit only a limited amount of predictive data as compared to the capacity of computerized procedures.

For more than a decade, serious thought has been given to a feasible solution of the overall personnel classification problem--the optimization of assignment of all personnel to all jobs. In theory, the problem was solved some time ago by the application of the transportation model. As applied to the problem of personnel assignment, the transportation model treats each man as a transportation source and the job areas or job families as the destination. But administrative and technical problems have slowed progress in applying these models in the actual military assignment process. Nevertheless, the work of the Army, Navy, and Air Force toward a feasible and practicable application of the transportation solution has begun to bear fruit.

Holdrege (1962) reported the results of Air Force research on OSCAR: Optimum Selection, Classification, and Assignment of Recruits. He proposed three mathematical models for use with computers and claimed that these models have the capability of providing management with meaningful

information for controlling a complex personnel system. Ward and Davis (1963) described a procedure whereby human judgments may be simulated on a computer. The essential procedure is to use predictor variables in an equation that best predicts the sample of decisions.

The Navy has also devoted a portion of its personnel research effort to the potentialities of computers in personnel assignment and manpower planning. Project MOON has produced a feasible model designed to simulate the effects of a number of variables that related to long-term manpower planning and projections (Knetz, 1963). With respect to personnel assignment, research is under way to automate procedures concerned with test scoring and with recording and employing data that constitute the bases for personnel assignment. The ultimate aim is the use of computers in optimal allocation of all personnel to all job categories in the Navy. While a suitable computer program for this purpose has been developed, a number of difficulties--largely administrative in nature--still stand in the way of immediate operational implementation.

Perhaps the most encouraging progress toward administrative acceptability of computerized optimal allocation has been reported by Boldt (1964) for the Army. Boldt's research is a logical outcome of the work of Brogden (1946, 1954, 1955) and Dwyer (1954, 1957). As Boldt indicates (1964, p.3),

> The figure of merit appropriate for allocation purposes is called the "allocation sum". It is obtained by adding, for all personnel to be allocated at a given time, scores on the aptitude areas appropriate for the MOS to which they are allocated. This allocation sum is to be maximized subject to the restraints that (1) a man can be assigned to one and only one job; and (2) the number of personnel assigned to a given job meets a prespecified demand.

In the Army solution, a matrix of "value on the job" indexes, the aptitude area scores, is used, with rows representing persons available for assignment and columns representing jobs. Boldt (1964) indicated that major administrative and technical problems that heretofore stood in the way of application of the transportation model to mass assignments of personnel to Army jobs have been resolved.

One major problem is that the demand for given numbers of personnel with specified aptitudes often exceeds the available supply. Under such circumstances the problem is indeterminate. The solution reached by the Army was to specify a cut-off at the 30th iteration, at which point the computer would "(a) minimize the remaining overages and shortages, if any, without regard to personnel quality over and above minimum prerequisites; and (b) print out the resulting assignments and quotas met" (Boldt, 1964, p. 6). The resulting print-out must then be examined for final decisions.

On the basis of this model, 5100 personnel were processed on a trial basis in 4½ hours. The results of this procedure were compared with results obtained by current Electric Accounting Machine (EAM) methods on an N of 1204, Table 7 shows that the proposed computer allocation method yielded average aptitude area scores that were equal to or higher than those obtained by the current EAM allocation method. On the average, the gain in mean aptitude area score was about 10 points, which is equal to one-half a standard deviation.

Table 7

COMPARISON OF AVERAGE APTITUDE AREA SCORES OBTAINED BY COMPUTER ALLOCATION AND BY CURRENT EAM ALLOCATION

Occupational Field	Computer Allocation Method (N = 5100)	EAM Allocation Method (N = 1204)
Infantry	109	98
Other Combat	111	102
Electronics	120	112
General Maintenance	117	105
Motor Maintenance	118	109
Clerical	114	114
General Technical	121	103

In view of the continued emphasis on differential assignment and the rather recent availability of computer facilities, the prospect is now very bright for developing feasible models for solution of the personnel assignment problem in all the services. Administrative and technical problems peculiar to each service will initially require compromises which will affect the accuracy of allocation. But even with compromises, computer techniques will undoubtedly result in allocations superior to those now accomplished by card punch and electrical accounting machine. As time goes on and proposed procedures such as the Army's are adopted in whole or in part, the advantages of computerized allocations will become even more apparent. In the near future, demands from military management for the development of more efficient personnel allocation techniques can be expected. The availability of computer methods will make use of larger bodies of data economically practicable, and classification research in the military services will be spurred to greater efforts to identify and utilize a greater range of predictive data than is now employed.

SUMMARY

The classification batteries of the military services have undergone considerable change since World War II. The Air Force battery has been subjected to the greatest change and is the only one that may be characterized as a selection-classification battery employed in the initial screening process. All the services conduct research aimed at improving predictive validity for school assignment and differential classification. Air Force testing is aimed at classification into four aptitude indexes; Army testing is aimed at classification into eight aptitude areas. Navy testing is aimed normally at classification into about 60 occupational ratings which in effect reduce to six occupational fields or composites. All the services are striving to implement computerized techniques to effect optimal assignment of all personnel, but the Army seems to be most advanced in this regard. Despite some administrative difficulties, the outlook for computerized optimal allocation in the military services is very promising.

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CHAPTER 4

LELAND D. BROKAW

NONCOGNITIVE MEASURES IN SELECTION OF OFFICER PERSONNEL

The military services have made extensive use of paper-and-pencil tests in their officer selection programs for many years. The aptitudes predictive of academic success in officer training are well identified and constant across the services, although there are specially named tests in each program. Measures of arithmetic reasoning, of verbal and spatial skills are virtually standard for prediction of success in the basic areas of officer training. The Air Force uses additional sensitive measures of spatial skills in its aircrew selection programs, but these are esoteric and depart from the general domain of officer selection as such. When research is turned to the interpersonal and leadership skills, the aptitude tests show less validity. Prediction of criteria of officer performance or leadership behavior depends on factors beyond those measured by the conventional aptitude test.

Noncognitive measures have been used in the selection and classification of military personnel for many years. Biographical inventories, attitude and preference scales, experience and activities inventories, and temperament and personality tests have been used in various programs. The heterogeneity of measures in this domain is highlighted by the generally adopted device of lumping them as "noncognitive" measures. Intuitively, as well as on the basis of proper validation, these devices have appealed to workers for use in the selection of leaders. Such measures seem to tap what a man will do rather than what a man can do.

AIR FORCE RESEARCH ON NONCOGNITIVE MEASURES

In a summary of a series of regression analyses against leadership criteria at the Air Force Academy, Creager and Miller (1961) state:

> The criterion used for predictive studies of leadership has been the Cadet Effectiveness Rating. Studies of the experimental and selection tests administered to date have indicated that this criterion is not generally predictable from such cognitive measures as aptitude and achievement tests. Considerable evidence has accumulated, however, to suggest that prediction is possible from noncognitive

inventories and related devices. Such results are not surprising in view of the noncognitive nature of the criterion itself.

The important of leadership or officer-like behavior has made it the prime target of research for many years. An early success in prediction was reported by Tupes (1957) in his account of a long-range research program initiated in 1949. This study embraced Officer Candidate School students as subjects and included, among other variables, a series of peer ratings based upon descriptive trait ratings which had been assembled and studied by Cattell (1947) and Fiske (1949).

The primary criteria for Tupes' investigation were officer effectiveness reports covering the period from the time of graduation from OCS until early in 1953. The period covered varied from early 1949 (Class 49-B) through 1951 (Class 1951 D). Although the number of OERs varied from 3.3 per officer from the first class to 1.3 for officers in the latest class, there was an average of 2.3 OERs for each of the 906 officers in the total sample. Academic grades and military grades achieved in OCS were retained as criteria for the peer ratings and as predictors for the later OERs. Procedures and results of the analyses based on 790 cases for whom complete data were available are best expressed in the investigator's own words:

> Peer ratings on 30 personality traits were obtained for candidates in each of six Officer Candidate School classes. Each trait was validated separately against OCS Military Grades, OCS Academic Grades, and later Officer Effectiveness Reports. The traits were grouped into clusters on the basis of their interrelationships and a multiple correlation computed between this reduced set of variables and the OER criterion. Obtained beta weights were then used to derive a set of simplified weights which were used to develop a composite trait rating for each OCS class separately. The validity of this composite was obtained for each of the three criteria for each OCS class and for the total group. Comparisons were made between the validity of the composite against OERs and the validity of Academic and Military Grades against the same criterion. Class-by-class patterns of validities were examined to see whether certain variations in the rating conditions had resulted in expected effects.
>
> A majority of the personality trait ratings were found to have substantial validity against each criterion. A multiple correlation between a reduced number of traits and OERs was highly significant (approximately numerically equal to the reliability of the criterion). The class-by-class validities of a composite based on

> simplified weights appeared to vary considerably; however, this variability did not appear to be a systematic function of differences in rating conditions. The validities of the trait rating composite against OERs were as high as, or higher than, the validities of a more global rating of leadership potential (the Military Grades) or of achievement as measured by Academic Grades. The composite correlated sufficiently low with Academic and Military Grades to indicate a certain amount of specific variance. When the trait rating composite was combined with Academic and Military Grades, the validity of the combination against OERs was higher than the validity of either alone. There would seem to be little doubt that personality trait ratings by peers, at least as obtained in the present study, are related to later successful on-the-job performance of officers.

The success enjoyed in this investigation triggered a series of studies to assess the characteristics of the descriptive trait ratings that had yielded unique prediction of the officer effectiveness report.

A series of analyses reported by Tupes and Christal (1958, 1961), Wherry, Stander, and Hopkins (1959), and Tupes and Kaplan (1961) demonstrated a stable factor structure for the trait ratings in many types of populations and repeatedly in Air Force samples. There is agreement across these studies that, while the five factors repeatedly identified are not the only factors operant in the personality domain, they are stable and therefore of possible use. The five factors were thus described by Tupes and Christal in 1958:

> The first factor seems to be that labeled by French (1953) as Surgency. It is highly loaded by the traits Assertiveness, Frankness, Energetic, Talkativeness, Adventurousness, and Sociability.
>
> Factor II is defined by Cooperativeness, Attentiveness, Good-Nature, Mild-Manner, Absence of Jealousy, and Emotional Maturity. It <u>corresponds very closely</u> to the factor labeled Agreeableness by French.
>
> Factor III has its highest loadings on the traits Responsibility, Conscientiousness, Orderliness, and Conventionality. This factor in many respects is like that labeled by French as Dependability or by Fiske as Conformity.
>
> Factor IV appears to be Emotional Stability. It is defined by Calmness, Placidity, Poise, and Lack of Neurotic or Hypochondriacal Tendencies. French lists the inverse of this factor as Emotionality.

Factor V is defined by Artistic, Cultured, Imaginative, and Polished, and appears to be the factor labeled by French as Culture.

The results of these analyses indicate that differences in samples, situations, and length of acquaintanceship have little effect on the factor structure underlying ratings of personality traits. We are not yet ready to suggest that these five factors are the primary personality factors and certainly they are not the only ones. Nor would we want to assert that our factor structure is the only one. Other investigators using the same data might arrive at a recurrent structure quite different from ours. Undoubtedly, studies can be designed and rating situations set up so that other and different factors would emerge. However, it does seem fairly safe to conclude that the factor structure of personality trait ratings is sufficiently invariant so that such ratings may be regarded as useful in the study of individual differences in personality and in the prediction of future behavior. If peer ratings are obtained on personality trait ratings within any convenient rating group, relationships found between those ratings and other measures may be generalized to other populations with some degree of safety. Trait ratings, it appears, may be used as the basis for studies designed to identify general laws and dynamics of interpersonal behavior, and as criteria for the development of personality tests which, when sufficiently valid, might be used instead of the trait ratings in situations (selection, for example) where such ratings are difficult or impossible to obtain.

The next step in exploiting the findings of validity of descriptive trait ratings in predicting later OER's and the discovery of the factor structure behind the ratings was to replicate the variance in a vehicle more flexible than the peer rating. It is apparent that peer ratings can be collected only from groups which have existed for sufficient time to have developed adequate basis for the rating process. The time may be quite brief, on the order of a week or so, as suggested by Hollander (1956) who, in research in the Navy Officer Candidate School, discovered stable peer ratings to exist after periods as brief as five days. Savings in time and money would result if the essential variance could be captured in a scale or questionnaire to be answered by the individual.

Accordingly, a contract was written with the University of Michigan, with Dr. Warren T. Norman as principal investigator, for an attempt to develop paper-and-pencil tests which would tap the variance of the five rating factors. He has reported the work of this contract in three reports (Norman, 1961a, 1961b, 1962).

A number of assessment measures were constructed to permit development of self-report devices to tap the five peer rating factors. In the construction of these measures, the attempt was made to minimize the influence of faking by respondents, to maximize the empirical validity of the self-report measures for the peer rating dimensions, and to minimize

the intercorrelations of the various scales. It was necessary, of course, to develop both criteria and predictor measures for use in the specialized setting available to the contractor. For both preliminary exploration and final validation of the instruments, paid male volunteers living in fraternity houses, cooperative groups, and dormitories at the University of Michigan were the subjects. These groups had the necessary background acquaintance for proper completion of the peer rating criteria.

In addition to the criterion rating scales, three kinds of inventory were constructed--the Descriptive Adjective Inventory (DAI), the Occupational Preference Inventory (OPI), and the Forced-Choice Self-Report Inventory (FCSRI). These were in part constructed of materials taken from other instruments in the field and of parallel material constructed by the project staff. A number of tests were also selected from other sources for inclusion in the experimental batteries. Among these were the Welsh Figure Preference Test (WFPT), Cattell's 16-Factor Objective-Analytic Test Battery (O-A Battery), a test of general ability called General Knowledge-A that had been extracted from the Cooperative General Culture Test, and a test of self-confidence called the Decision Analysis Test. Two Air Force experimental tests were included--Culture-E, a measure of information in esthetics, and Self-Crediting V, a measure of risk-taking tendencies or self-confidence.

The criterion peer ratings and test scores were collected in 51 rating groups totaling 456 male students for whom complete data were available. These cases were divided into two equivalent samples, with care taken to equate the factors of fraternity or dormitory residence, college class year, and the factor structure of the criterion ratings.

Keys for each of the five factors were empirically derived in each of these groups, and the validity of each key was determined in the other sample. After acceptance of the keys as being of satisfactory validity, regression weights for each key based on the sample in which the key was derived were applied to the other sample in a double-cross validation analysis.

The best predictors of the peer ratings for each of the five factors were the various keys developed for two instruments designed for the study--the Descriptive Adjective Inventory and the Forced-Choice Self-Report Inventory. Zero-order validities were highest for these measures and their multiple correlation coefficients were not significantly improved by addition of other tests.

Cross-validity coefficients ranged from .44 to .26 for the peer rating criteria. Prediction of the first factor, Surgency, was best, of the fourth factor, Emotional Stability, lowest. All the cross-validity coefficients were of a magnitude encouraging in the area of temperament or personality evaluation.

With the analysis just described, Dr. Norman's contract was completed. The Air Force is moving forward with a research program to clarify and improve the work initiated. We have collected peer rating data and test data for large samples of Officer Training School students. As the data mature we will be able to determine the validity of the peer ratings and of the questionnaire data and to compare their effectiveness as predictors of officer success in the Air Force operational evaluation program.

NONCOGNITIVE MEASURES USED BY THE U. S. ARMY

The United States Army officer selection programs for the United States Military Academy, the Reserve Officer Training Corps, and the Officer Candidate School indicate the usefulness of noncognitive measures in officer selection programs. In addition to the necessary physical and moral screening, there is a dual evaluation of the individual's mental competence to handle the demands of the officer's task and of his leadership skills. The present status of Army research in these areas is well described in a series of reports issued by the U. S. Army Personnel Research Office (Brogden et al, 1952; Haggerty, 1953; and Parrish and Drucker, 1957).

In each program, similar measures of leadership appear. These include an objectively scored report of officer potential, an inventory of personal and background factors, and a board interview procedure. In the OCS program, the report of officer potential is an intensive rating of the individual's performance as an enlisted man which would indicate his potential officer qualities. In ROTC selection--in which there is much less opportunity for leadership evaluation--the program includes a biographical inventory blank and ratings of military performance. The latter are basic to the identification of distinguished graduates of the ROTC program, as well as to the elimination of unpromising cadets. Similarly, in research for the USMA program, aptitude for the service ratings serve as criteria for the validation of selection measures and also as predictors of later officer effectiveness. Both the ROTC and the USMA use the device of summer encampments to create meaningful situations in which leadership qualities may be objectively assessed.

The leadership measures in the three programs are accompanied in varying degrees by measures of intellectual abilities. In OCS selection, general competence as evaluated by a general aptitude score suffices. In the ROTC program, a more extensive battery to predict academic success is applied. And in the USMA program, a detailed battery of tests assesses the probabilities of success in the academic program.

Validation of intellectual measures and leadership predictors against garrison and combat criteria indicates that a major portion of the predictable variance is covered by the leadership measures. The most enduring validity has been found for peer rating measures and the USMA aptitude for the service ratings. In this domain, Air Force and Army have exactly parallel results.

The Army is involved in a comprehensive study of the possibility of differential classification of Army officers by major areas of assignment. This study involves the administration of a series of tests called the Differential Officer Battery and the collection of situational criteria in technical, administrative, and combat areas.

The battery has been administered to a large sample of incoming officers. Predictors of six types were retained in the Differential Officer Battery. As reported by Willemin (1964), these include:

1. Biographical and self-description instruments. These measure background, personality characteristics, attitudes, and expressed interests.

2. Information tests. Instruments in various subject matter areas follow the hypothesis that information gained, particularly without formal training in a subject, reflects interest in the area. Information specific to military tactics, logistics, finance, and non-military general information is included.

3. Social perception tests. These tests evaluate ability to estimate the opinions of others in a group or to perceive similarity or differences in the views or attitudes of individuals.

4. Command judgment. A motion picture test of speeded practical judgment has been devised.

5. Tests of physical skills and stamina. These are measures of physical proficiency similar to those which have been found predictive of leadership ratings of USMA cadets and the performance of enlisted personnel in Arctic maneuvers.

6. Peer evaluations. Peer ratings were collected at each Branch school during the seventh week of the Officer Orientation Course.

The situational criteria were collected late in the tour (after about 18 months) at the Officer Evaluation Center at Fort McClellan. In a format of tasks encountered in an assignment at a Military Advisory and Assistance Group, each officer was evaluated in technical, administrative, and combat tasks. There were five exercises in each area. The script took each evaluated officer through these tasks in a continuous order. Thus, officers trained and assigned in each of these areas were evaluated in all three areas, permitting analysis of the Differential Officer Battery so as to maximize its validity for each area.

This study is not yet complete, but is well along in the collection of data. The first differential validity analysis will occur in 1964-65 as sufficient cases accumulate. It is anticipated that the resulting measures will be applied first in the ROTC program, as validation studies indicate the proper use for the predictors involved.

NONCOGNITIVE MEASURES USED BY THE NAVY

The Navy has accomplished research on a number of noncognitive selection devices against various criteria of success. Selection interviews for NROTC students and for OCS candidates have shown little validity except when focussed on the point of career planning, as reported by Rimland (1959). Further efforts to exploit the areas of self-reported background information and to assess interest through information tests have been reported by LaGaipa (1960). A battery of eight experimental biographical and self-description inventories were administered to two OCS classes and validated against fleet criteria a year later. None of the paper-and-pencil devices was identified as a useful predictor of general fleet criteria--two of the tests were valid for criteria derived from Shore billets, but none for the Fleet. The two tests which did show Shore validity were the Cooperation Test, a forced-choice self-descriptive inventory, and the Petty Officer Description Scale, another forced-choice instrument hinging upon the differences between descriptions of successful Petty Officer supervisors obtained from enlisted personnel and from officers.

An outcome of the research which parallels Army and Air Force experience lay in the validity of OCS peer ratings of aptitude for military service for the criterion of the officer fitness reports.

An investigation of the extent to which physical proficiency and sports information measures were correlated with Naval success has been reported by Rimland (1961). Such measures are used by both the Air Force and the Army in their academy selection programs, and show consistent validity for such measures of success as the cadet's aptitude for commissioned service rating. The Navy found low--barely significant--validity for career decisions and fitness reports, and concluded that the tests would be of limited value in the Navy selection system. The physical proficiency tests did show some promise for those specialties which were physically demanding, but did not warrant adoption as a screen for all potential officers.

SUMMARY

The military services have cooperatively and independently arrived at aptitude measures for the selection of officers which are parallel in content across the services. A review of recent research on officer selection instruments in the noncognitive domain reveals that all three services have found that peer ratings collected during training are predictive of later officer performance as measured by the operational evaluative instruments. All three have had difficulty in the attempt to identify paper-and-pencil personality tests predictive of operational criteria of officer effectiveness.

The Air Force is attempting a possible breakthrough in the evaluation of instruments intended to replicate the variance of the peer rating situation. The Army is conducting an extensive laboratory criterion development exercise in an attempt to identify differentially valid factors in a paper-and-pencil test battery. The Navy is depending on a system of interviews and paper-and-pencil tests, coupled with the collection of various data descriptive of school success.

It is entirely possible that the military services stand upon the threshold of a capability for the identification of what a man will do, as well as what a man can do.

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PART II

REVIEW OF
CONTEMPORARY MILITARY TRAINING RESEARCH: THE STATE OF TRAINING TECHNOLOGY AND STUDIES OF MOTIVATION AND ATTITUDES IN LEARNING

INTRODUCTION TO PART II

The principal participant and chairman of Part II, on military training, is Dr. Meredith P. Crawford, Director of the Human Resources Research Office of the George Washington University. In Chapter 5, Dr. Crawford reviews recent research on individual and small unit training with special reference to research on leadership behavior and motivation.

Dr. Crawford enlisted the participation of Dr. Gordon Eckstrand of the Behavioral Sciences Research Laboratory, Wright-Patterson Air Force Base, and of Dr. Glenn L. Bryan, Office of Naval Research, Washington, D. C.

In Chapter 6, Dr. Eckstrand defines the technology of training as "the things a training institution characteristically does in setting up and managing a training program to produce men capable of 'performing effectively'". In discussing the body of knowledge and techniques applicable to practical problems encountered in designing training systems, he makes a distinction between the psychology of training and the psychology of learning.

CHAPTER 5

MEREDITH P. CRAWFORD

TRAINING FOR LEADERSHIP, COMMAND, AND TEAM FUNCTION

SCOPE

During the past decade, research and development in military training have broadened in scope. In 1951, Wolfle wrote, "The psychology of training is the applied psychology of learning" (1951, p. 1276). While he devoted some space to the question of what should be taught, that is, curriculum content, Wolfle's main emphasis was on those manipulable conditions which promote learning.

Since then, increasing attention has been focused on the study of the job, the team, the organization, and the man-machine system in which the trained man will operate. Recent outlines of the steps required to develop a training program (Crawford, 1962; Eckstrand, 1964) begin with a study of the system and the job. It may be fair to say that, during the last ten years, studies of the curriculum which have derived from examination of the job and the system have made greater contributions than research in training media. This assertion seems to ignore spectacular advances through programmed instruction. However, the precise determination of training objectives, based on job study, is usually fundamental to developing an efficient series of training frames for effective job-oriented programmed instruction.

In considering training research and development from either the methodological or the substantive point of view, the ramifications of interest they engender are almost infinite. Related to methodology, which we may call the developing technology of training, are the areas of operations research and systems analysis, techniques of job analysis and task and skill analysis, the experimental psychology of human learning, studies of motivation and incentives, and the techniques of measurement of achievement and performance--in short, a wide range of concern within and outside the field of psychology.

The substantive studies--those leading to specific military training programs for current and future systems--embrace an equally wide range of related interest and information necessary to the training researcher. The researcher must know the particular military system and setting, current policies, trends, missions, and especially the personnel policies of the service or branch in which he works. In addition, he must keep abreast of actual or potential contributions to understanding and improving human performance made by fellow human factors

scientists in selection, classification, human engineering, and personnel psychology, as these relate to his field of interest.

In view of the mass of material relevant to research in training in the services, panel members decided to eliminate many topics and concentrate on a few. Certain major substantive topics were assigned to Dr. Bryan and to me, and the methodological and technological areas to Dr. Eckstrand. Substantive topics chosen are technical training and anticipation of training requirements (Bryan), and training for leadership, command, and team function (Crawford).

Following this arbitrary dissection of the whole body, a few remarks are in order on what has been left out. For example, no review will be presented on recruit training. Some studies are under way in all three services, with a heavy concentration in this area by the HumRRO Training Center Research Unit at Fort Ord, where both research and consultation have been of use to the Army in significant changes now under way in the content and administration of basic training.

Again work is going on in all three service toward developing and improving training programs for many occupational specialties. The extensive development of programmed instruction in the Air Force, reported by Ofiesh (1963), represents a major advance in training efficiency in that service. Recent work has been done in the Navy on doppler and sonar training. Under Army auspices, in addition to much work on electronics maintenance training, new curricula have been developed for the aerial observer, for the infantryman in land navigation and fundamental combat skills, for the operators of air defense equipment, and for vehicular mechanics.

Flying training is another area which has been omitted from our presentation. The Navy has, in recent years, produced studies in training for jet aircraft. The HumRRO Unit at the Army Aviation Center (Fort Rucker) has done research and development on elementary training in both fixed and rotary wing aircraft, problems of low-altitude high-speed flying, and gunnery training in the armed helicopter.

Research on more general training matters neglected by this panel would include a few bits of data on motivation for training under various circumstances, and the already large volume of literature on psychological considerations in the development of training devices. Many excellent papers on this topic have recently become available (as for example, Smode, Gruber, and Ely, 1962, 1963) which summarize much information related to developing all kinds of training programs. This fundamental technology belies the artificial distinction between interests in training and in training devices.

Another large topic not being covered is work on training in many kinds of specific skills, usable in a variety of occupational specialities. Excluded, for example, are recent studies in foreign language training

which use automated methods, research on training in perceptual skills, and studies on the determinants of transfer of training among related military programs.

It would also be useful, had we the time, to review the kind of statements of doctrine about training which are current in the various service. For example, a recent publication of the Air Training Command (1963) sets up a very forward looking system of parameters in which to plan new training for the Air Force. Also, in this connection, time could profitably be devoted to practical considerations involved in implementing the results of training research and development and to theoretical problems arising from attempts to generalize from studies of the engineering type (see Finan, 1962).

In deploying his forces for strategic or tactical purposes, the military commander must assess the strength, equipment, and readiness of units. He is almost equally concerned with the capabilities of their commanders. In similar fashion, current research in leadership, command, and management and in the structure and functions of teams, units, and organizations reveals the intimate relation of fact and theory about the function of the organization and its head. While military psychologists have shown an increasing recognition that the group and its leader must be considered together, particular investigations have generally concerned either leadership and command or teams and units. Because military units are filled by pipeline streams from many combat, technical, and command training programs, this division of research and development in our laboratories has been a natural consequence.

Although studies reported in this presentation will be divided between leadership and command on the one hand, and team training on the other, I hope that evidence that researchers have not compartmentalized their thinking will be apparent.

Studies pertaining to command will be further subdivided between those which emphasize the interpersonal aspects of command, connoted by the term leadership, and those which relate to training and organizational and technical responsibilities. A further cut will be made in each topic between research and development. For this discussion, studies aimed at obtaining information about the function of commanders and units will be classified as research. Efforts to build specific training programs will fall under development. Finally, one further distinction will be made between studies on command; those pertaining to noncommissioned officers will be grouped separately from those on officers.

These rather artificial categories have been chosen to avoid a dull recital of abstracts and to call attention to one set of relationships. Disadvantages of the classification scheme include the splitting of accounts of many investigations which have proceeded through an orderly sequence of research and development. Also, the division between work on NCO's and officers may obscure many communalities in their functions. Perhaps we can tie some related threads together at the end.

INTERPERSONAL ASPECTS OF LEADERSHIP AND COMMAND

Papers presented at the Conference on Leadership and Interpersonal Behavior at Louisiana State University in 1960 comprehensively summarize research during the 1950's, particularly that under the sponsorship of the Office of Naval Research. Conference proceedings, edited by Petrullo and Bass (1961), are rich in coverage of theoretical points of view and empirical data from laboratory and field situations. This book represents a starting point for the present review.

One of the most important contributions of this publication to an understanding of military leadership is found in the many instances where leadership function is viewed in terms of the total organization (chapters by Chris Argyris and by Rensis Likert). The reports by M. Dean Havron and Joseph E. McGrath of work on leadership in small military units are most relevant, as are those by John C. Flanagan on work by the American Institute for Research in leadership and small groups and Fred E. Fiedler's concise account of his several studies on the "assumed similarity of opposites" variable.

Another background reference to the work in the 1950's is Hahn's bibliography (American Institute for Research, 1961b). The titles on leadership research are divided among characteristics, skills, acts, and training. Only some ten percent of the references concern training.

RESEARCH ON LEADERSHIP BEHAVIOR

Noncommissioned Officers. An important earlier study on leadership and squad effectiveness in Korean combat was not included in either of the above reviews. Clark (1955) and his team interviewed the members of 81 rifle squads on the front line during the winter of 1953 to determine some of the factors related to effectiveness of squads.

Sociometric indices were obtained of group cohesiveness, patterns of acceptance among squad mates and of platoon members outside the squad, and interactions related to sociability, fighting, and recognition of military skills. Two criterion measures of squad effectiveness were developed: (1) a weighted composite of ratings made at the battalion, company, and platoon levels, and (2) results of a Q-sort of records of squad behavior made by officers with recent Korean combat experience at the platoon level.

Detailed descriptions developed for 69 of the squads revealed consistent performances of individuals which were classified as five leadership functions: (1) managing the squad, (2) defining rules and procedures for appropriate behavior, (3) performing as a model, (4) teaching squad mates, and (2) sustaining squad mates with emotional support. These functions occurred in the various squads with differing frequencies;

managing was observed in all but two of the total 69 squads. Defining occurred in 52, and the other three functions were seen in from 25 to 30 squads each.

The occurrence of these functions in squads was positively related to both combat criteria, significantly so to the Q-sort measures. Only one squad leader performed all five. The assistant squad leader often carried out the management function, while defining, modeling, teaching, and sustaining were done by leaders, assistant leaders, or other squad members. In theoretical terms, Clark saw these leadership functions as acting on the squad's value structure and thus indirectly affecting performance. Indices of these value structures, derived from sociometric choices relating to sociability, fighting, and crediting each other with skills, showed some significant relations with the combat criteria.

Since 1960, a number of studies of Navy petty officers have appeared. In the first, a questionnaire survey was made of the utilization of 1690 petty officers (Bureau of Naval Personnel, 1960). It was found that superior ratings of job performance were awarded in greater frequency to graduates of the five-week schools than those of the one-week schools. Raters believed the schools to be effective in teaching leadership, although no information was given on how students were selected. Another study (Mayo and DuBois, 1963) indicates a gain in leadership rating following schooling.

Concerning important behavioral characteristics of petty officers, three studies provide some information about the influence of petty officers on their men. By means of questionnaires answered by officers, CPO's, and subordinate enlisted men, Spector, Clark, and Glickman (1960) obtained some information on characteristics of CPO's which influence attitudes and morale of their men. Analyses revealed two of five factors to be of consequence: first, the CPO's regard for the regular Navy and, second, consideration shown his men. The first was positively and the second negatively related to subordinate expressed interest in a Navy career.

Two studies by Kipnis and his associates (Kipnis, Lane, and Frankfort, 1961; Kipnis and Lane, 1962) examined the kinds of actions petty officers took when they judged that a man's performance was below Navy standards. One study indicated that senior petty officers tend to deal with men on interpersonal terms while junior PO's characteristically passed the problem up the chain of command by informal or formal action. In the second study this relation to rank was not significant, but there was evidence that those of any rank who indicated greater self-confidence in their leadership abilities on a special test form tended to deal interpersonally.

In 1961, Hahn and his AIR associates gathered critical incident data from petty officers during the research phase of a training development project (Trittipoe and Hahn, 1961). He was able to classify these

incidents into eight kinds of problem situations, including assignment and supervision of work, training, discipline, technical competence of men, and personnel and emergency actions.

With Army NCO's of infantry and artillery teams, Ziller (1963) found a small positive correlation between the leader's assumed similarity score and ratings of team effectiveness. To explain this divergence from Fiedler's findings, Ziller assumed that Army NCO's have little choice of subordinates so they devote their efforts to promoting the proficiency of all unit members rather than to selecting superior ones for intensive development. Such variations from earlier findings on the assumed similarity of opposites are also reported in a recent paper by Fiedler himself (1963). However, with West Point cadets in competitive squad problems, Gottheil (1963) found evidence for the negative ASO relationship, as well as positive correlations between various leader attitudes and squad morale.

An experimental study using <u>ad hoc</u> four-man groups of Army enlisted men of various grades has just been completed by Drucker (1964). He appointed leaders and conveyed different degrees of power, authority, and responsibility to each. The teams worked at a signal monitoring task and three cognitive tasks for one day. First-order relations between the three leader variables and team performance were few, but combined effects of authority and responsibility appeared on different tasks.

At the outset of a comprehensive R&D program for leadership training of potential Army NCO's, Hood and his associates at the HumRRO Unit at Fort Ord did a large amount of background research (Hood, 1960). One study accomplished a survey of the programs and methods in noncommissioned officer academies (Kern, 1958). The teaching of leadership principles rather than the provision of some kind of practice in leadership acts characterizes the main features of programs designed to build NCO confidence. In a second study (Showel and Peterson, 1958), a total of 3960 critical incidents were obtained about squad leaders from 135 supervisors and a like number of subordinates in four infantry divisions and an armor cavalry regiment in Europe. Sorted into nine categories, these data provided considerable insight into typical NCO behavior as seen from above and below. Particular attention was paid to conflicts in role, resulting from the NCO's intermediate command position. Several other minor studies of NCO behavior were also made. In addition, a training guide for potential NCO's was prepared from these studies (U. S. Continental Army Command, 1963).

<u>Officers</u>. To gather background information for development of leadership training, Lange, Jacobs, and their associates carried out two studies to answer the question, "How does the leader function to maintain high motivation and high standards of performance among his followers?" (Lange, 1962, p. 286). They took the view that the leader function is one of modifying the motivation and capability of group members to perform assigned duties.

The sample drawn for the first study (Lange et al., 1958) comprised 42 platoon leaders from two infantry regiments of a combat-ready division in the United States. Interviews with both superiors and subordinates obtained retrospective reports of actual behavior of the platoon leaders in specified situations. Content analyses of these interviews resulted in the recognition of 140 "dimensions" of behavior and situational context, on which each incident of leader-follower interaction was scorable. Frequencies with which each leader performed various behaviors were related to ratings of the leaders by both subordinates and superiors. These two sets of judgments offered a pair of remarkably similar criteria. The leadership behaviors related to these criteria fell into five categories:

(1) Giving information that facilitates the improvement of group performance.
(2) Establishing high standards of expected performance.
(3) Using reward and punishment appropriately.
(4) Handling disruptive influences in the unit.
(5) Obtaining information from group members on matters relating to the execution of the first four functions.

These findings were checked in a second study (Lange and Jacobs, 1960) in which a questionnaire instrument was developed to measure the variables identified. This instrument was used with junior officers in another combat division to measure the frequency with which leadership behaviors occurred. Results of the first study were confirmed and thus provided a comprehensive basis on which to develop leadership training.

Mention should be made of two HumRRO studies now in progress which bracket leadership training at both ends. In the first, a study of the college Army ROTC program has recently gotten under way. The second concerns leadership and the exercise of command at the division level. A source book is being prepared (Olmstead, 1964) which will integrate research results from a variety of behavioral sciences with practical military commentaries on the exercise of command at higher echelons. This work is intended to serve both as a reference volume for the Army Command and General Staff College and as a basis for planning research in the areas of high-level leadership and command.

DEVELOPMENT OF TRAINING IN LEADERSHIP

Noncommissioned Officers. The critical incidents collected by Hahn and associates on Navy petty officer behavior formed the basis for development of 15 role-playing situations which were also rendered in case study form (Trittipoe and Hahn, 1961; American Institute for Research, 1961a). After intermediate tests, final evaluation of both role playing and case study work was accomplished by measuring the

agreement between assessments of student performance in this training by other petty officers and research personnel. Also, ratings of probable job performance and mutual rankings of men during discussion groups were obtained. Modest significant correlations were found among these three measures. Measures taken during this training showed substantial positive relationships to performance in petty officer school, but only small and nonsignificant correlations with the next regular six-month performance evaluation on the job. During the course of this work a text on leadership for petty officers was prepared (Hahn and Trittipoe, 1961).

We return now to the Army study of NCO leadership to trace the development of a system for training potential nocommissioned officers during their first 16 weeks in the Army. Having made the study of existing NCO academies and completed the analyses of critical incidents collected in several Army divisions, referred to earlier, Hood and his research team moved toward the engineering phase of the work. Some kind of training system involving instruction and practice in leadership during Advanced Individual Training was the goal. Further studies relating to various aspects and options of possible training systems were made. A cooperative working relationship was established between the U. S. Army Personnel Research Office and HumRRO to handle selection aspects of the work.

First, a longitudinal study (Hood, 1963a) followed two companies of Reserve Forces Act trainees through their entire six-month career in the Army. Peer ratings, performance tests, written tests of knowledge, selection devices, and measures of motivation and attitudes taken during Basic, Advanced Individual, and Unit training were intercorrelated to provide background information on the kind of situation in which leadership training was to be developed. A second study examined the Advanced Individual Training program for possible shortening to make room for leadership training. In a third (Showel, 1963), the attitudes of trainees toward the Army and their perceptions of the NCO's role were determined by questionnaire and interview techniques. In the fourth study, selected trainees were given leadership training concurrent with Advanced Individual Training where they occupied leadership positions (Sloan et al., 1963). In the final pilot study, a four-week training program in leadership and military subjects was given to selected graduates of Basic Combat Training, who went through Advanced Individual Training as acting squad leaders under the direction of "leadership NCO's" (Sloan et al.).

These studies provided information on three ways of combining leadership training and practice with Advanced Individual Training: (1) by recycling students for the second eight-weeks, (2) by integrating the training with the second eight-weeks, and (3) by a special course between the first and second eight-weeks. At this point in the development, these alternative solutions were discussed with Headquarters, U. S. Continental Army Command, the responsible Army Headquarters, to

obtain guidance on which method would be most suitable for Army adoption. The short-course method was selected.

Beginning in January 1961, and continuing throughout most of the rest of the year, the main experiment took place. Principal interest was centered on the 400 trainee leaders who acted as squad leaders, and the 100 who acted as platoon sergeants. Also, data were obtained on 100 officers and 100 cadre sergeants commanding these trainees and on the 800 fire-team leaders and 3200 followers who were supervised by the trainee squad leaders.

In this complex Latin Square design, the following independent variables were involved: (1) aptitude level of the trainee leader, (2) peer rating of the trainee leader, (3) duration of the preparatory course, (4) nature of the training method, (5) supporting cost of the training method, (6) degree of training of the cadre, (7) differences in military occupational specialty of trainees, (8) differences between training companies to which student leaders were assigned.

Seven dependent variables included the following: (1) motivation and morale of trainee leaders, (2) global assessment of their leadership aptitude by peers, superiors, and followers, (3) specific observations of trainee leadership behavior by peers, superiors, and followers, (4) performance measures of the squads headed by trainee leaders, (5) written tests of leadership knowledge of trainee leaders, (6) measures of trainee leader's influence on followers, and (7) various administrative records.

Analysis of all these variables is now under way. One report on the climate for trainee leaders is currently available (Hood, 1963b). This report concludes: "It is clear that a 'leadership climate' influence can be discerned in the matrix of data, but its trace is not always direct or obvious."

Because of the Army buildup during the Berlin crisis in 1961, steps were taken by the Army to implement this work almost immediately after the conclusion of the experimental runs. Today there are leader preparation courses in operation in all Army Training Centers.

Officers. We return now to the work on junior Army officer training by Lange and his associates. Before they undertook the analyses of leadership behavior in combat-ready units described in two studies cited, the research team completed a study in leadership training media stemming from the work of Launor Carter. Sound motion pictures depicted real life leadership problems from garrison and combat. The films ended before the problem was solved by the leader in the story. Students then discussed and acted out various solutions for mutual criticisms under the guidance of an instructor using an instructor's manual prepared by the researchers. Army training films based on these prototypes have found extensive use in officer and noncommissioned officer training (Lange, Rittenhouse, and Atkinson, 1956).

Using the results of the research on leadership behavior referred to previously, and with the experience gained from developing the motion picture technique, the final engineering step in the program was completed (Jacobs, 1963). A 20-hour period of instruction was developed in which leadership problems were presented from audio tape recorders and students worked through a textbook in small unit leadership. This completed package, which includes an instructor's manual, was given several trial administrations with junior officers at Fort Benning and was recommended for adoption in ROTC programs where it is now in use. While the developed training package has not been subjected to follow-up study against criteria which measure either the leadership behavior of the officer or the performance of his group, considerable user satisfaction has been expressed for the program. Its efficacy has been assumed because it was based on extensive research on leadership behavior.

During the course of these studies, Lange (1962) formulated a general theory of leadership behavior. He recognizes the importance of group codes and identifies the leadership functions of defining, motivating performance, handling disrupting influences, and getting information in terms of their effects on the formulation and enforcement of this code, which seems to determine so much of group performance.

A source of important research findings on behavior of junior Army officers is the Officer Prediction study now being conducted by the Army Personnel Research Office. Performance in situational criterion tests of both administrative and tactical knowledge and skill is being related to assessment variables and efficiency reports for a large sample of officers during their first tour of duty (Willemin, 1964).

ORGANIZATIONAL AND TECHNICAL ASPECTS OF COMMAND

Fundamental to the effective performance of a military leader at any echelon is technical competence in particular weapons, equipment, and tactics as well as understanding of the organizational and administrative relationships and responsibilities which are his. A number of HumRRO efforts have been and are devoted to this aspect of officer and non-commissioned officer training. In each case, a comprehensive task, ultimately directed toward the construction of a training program, has begun with a study of the military system in which the officer or NCO is to operate and a determination of his particular job characteristics (e.g., Cook, 1963, and Warnick and Baker, 1964). From these, requisite knowledges and skills are derived and training objectives formulated.

RESEARCH ON JOB DUTIES AND RESPONSIBILITIES

In the field of Armor a continuing series of investigations has been under way at the HumRRO Unit at Fort Knox. An early study in the United States and Europe determined the job requirements for tank crew members (Baker, 1958), including those of the tank commander. The latter's responsibilities include: (1) controlling the immediate activities of the tank under platoon leader command, (2) supervising the crew, (3) gathering, processing, and distributing information, and (4) performing operational duties. As a self-study aid, The Tank Commander's Guide was prepared (Cook, Warnick, and Baker, 1963).

At the platoon level in Armor, a study of the j requirements of the platoon leader (officer) and the platoon sergea as made in 40 armored units in this country and Europe (Baker, 196. Roach and Baker, 1961). A list of more than 300 job duties, compiled from Army literature and interviews, was administered to approximately 400 officers in these units, from battalion commanders to platoon sergeants, for rating of combat importance. The same list served, with different instructions, for both platoon leader and platoon sergeant. In addition, written logs of all activities performed during the preceding 48 hours were obtained from 166 platoon leaders and 257 platoon sergeants in operating units. From these data, schedules of combat job requirements were compiled for the two positions under study. Eight major duties, involving from 2 to 12 operations, were sorted out along with the reported knowledge factors and responsibilities associated with each. These extensive analyses provided the basis for a determination of the objectives of new training to be developed.

A similar line of investigation has been under way at the HumRRO Air Defense Unit at Fort Bliss. The platoon leaders for NIKE AJAX and HERCULES air defense missile crews have been studied through successive modifications of this system over the last several years (Ammerman, 1964a, 1964b).

Formulation of the job descriptions began with the preparation of provisional job descriptions based on review of manuals, attendance at school courses, interviews, and job observations (Darby et al., 1959). They were then checked in intensive interviews with all officers at 12 NIKE AJAX batteries and were criticized by competent agencies at Fort Bliss. From these revised job descriptions, training-need checklists were prepared and officers from 72 batteries were asked to judge selected activities for their jobs in terms of (1) importance for battery operation, (2) degree of proficiency required, and (3) priority for training (Darby, Brown, and Morse, 1959). Job requirements lists from this study were prepared for students in the Air Defense School officer courses. To keep up with the changes from NIKE AJAX to its successor, HERCULES, these job descriptions were revised by field interviews and observations, consultation of new manuals, and interviews at Air Defense Center agencies (Haverland and Fightmaster, 1960). A more refined analysis of junior Air Defense officer jobs is being completed by Ammerman (1964b).

A comparable kind of study of the job requirements for the junior infantry officer in combat is now under way at the HumRRO Unit at Fort Benning. Combat reports, vault files at the Infantry School, combat incident reports and analyses, and interviews in operationally ready units on maneuver in CONUS and Europe are providing the basis of a statement of job requirements and will supply a good deal of content material to supplement existing training.

DEVELOPMENT OF TRAINING IN COMMAND

We turn now to the kinds of training programs in the exercise of command that are based on these background research studies. For use in informal training of tank commanders in their operating units, two forms of a standardized, simulated, combat mission test using live tanks have been constructed (Schwartz and Floyd, 1963). Test-retest reliabilities, corrected for practice effects, range from .42 to .62. The test is diagnostic in nature.

For Armor platoon leaders and platoon sergeants, a set of 10 tactical training exercises was developed to provide practice in six essential combat skills and several aspects of platoon tactics (Baker et al., 1964). For indoor practice on these exercises, two miniature training devices were developed: (1) the Miniature Armor Battlefield, and (2) the Combat Decisions Game. The former may be used in training platoon leaders and tank crews, while the latter is for platoon leaders and tank commanders only. The Miniature Armor Battlefield is built to a scale of 1:25 and employs self-propelled miniature tanks, controlled by radio by the tank commander, seated on a movable platform with other crew and platoon members above the model terrain. The Combat Decisions Game, using a scale of 1:115 (HO gauge), requires tank commanders to move model tanks over a grid square with a pusher at a realistic speed. In both problems, platoon leaders communicate with their platoon commanders above and tank commanders below with standard tank radio equipment.

The effectiveness of the training given by each of these techniques was measured for experimental and control groups of platoon leaders with two instruments: (1) an objectively scored field test using real tanks and blank ammunition in a platoon mission against a live agressor force (Baker and Cook, 1963), and (2) an essay-type test of 11 platoon-level combat problems requiring tactical decisions and command actions by the platoon leader. A written test of Armor knowledge was also used.

Results of the field testing of 20 experimental leaders trained on the Miniature Armor Battlefield and 20 controls indicated a significant superiority of 18.3% of trained over non-trained and a 5% superiority of trained over field-experienced platoon leaders not given these training exercises. Similar results obtained with the less elaborate Combat Decisions Game also favored the experimentally trained groups.

This study indicates the feasibility of providing realistic tactical training indoors. The extent to which those aspects of the tank platoon leader's job call for leadership, as opposed to sound tactical decision making, command, and control, is difficult to estimate. While offering variety of terrain and enemy action encountered, the situations probably were more nearly "established" than "emergent", in the terminology of Boguslaw and Porter (1962). To look at it another way, however, all tactical situations are by their very nature more or less emergent, requiring commanders to produce new solutions and new behaviors, which combine insightful tactical decisions with motivating leadership in implementation of these tactical choices. The motivational requirements are hard to simulate.

For the training of Air Defense officers, an on-site proficiency test has been built and tested (Morse et al., 1960), a refined method for determining the objectives of junior officers is nearing completion (Ammerman, 1964a), and programed instructional material is now under final test.

TEAM TRAINING

Having reviewed the current work on training for leadership and command, we turn now to investigations of team function and team training. While teams do not operate without leaders, and commanders have no functions apart from their units, it has been profitable to carry on research in which the team, rather than the leader, is the primary focus. The literature is much richer in theoretical studies and reports of laboratory experiments than in descriptions of training program development. Much is yet to be learned about teams before new techniques and principles can be applied to improve current practice. We have learned, however, from the original work by the Rand Corporation that when teams work together they learn and improve their performance. We have much to find out about how this learning occurs.

From his recent review of the literature, Glanzer (1962) concludes that the two most important aspects of team training needing further study are the processes of monitoring individual behavior and supplying feedback and reinforcement to team members. One conclusion from another recent comprehensive review by Boguslaw and Porter (1962) is that effective team training is best done on the job where both "established" and "emergent" situations occur, providing varied opportunities for learning by the crew. To dig a little more deeply into the variables which seem to influence crew effectiveness, George (1962) offers a detailed discussion of the literature from 1955 to 1962. He concludes that group codes are of paramount importance in determining motivation of group members, and that activation theory provides a guide to the understanding of the amount of group stimulation which will optimize efficiency. Additional conclusions by George will be discussed later when we come to an account of the work he is beginning on the training of infantry teams.

A wealth of recent summaries of laboratory experimentation is available (Glanzer and Glaser, 1959, 1961; Golembiewski, 1962; Hare, 1962; Stogdill, 1959). Sophisticated analytical treatments of small group interactions were presented at the Stanford symposium in 1961 (Criswell, Solomon, and Suppes, 1962). Coming somewhat closer to the practicalities of military team training are some papers in Guetzkow's readings in simulation in social science (1962), and the Havron-McGrath chapter in Petrullo and Bass (1961), referred to previously. An instructive discussion on air crew training, between research and military personnel, occurred at Castle Air Force Base in 1960 (Hood et al., 1960). Finally, recently developed techniques for studying team training are well summarized by Smode (1962).

RESEARCH ON TEAM FUNCTION

The work of Alexander, Kepner, and Tregoe (1962) concerns the effectiveness of the knowledge of results in the performance of crews in air-direction centers. Four crews at four coastal locations were matched and placed in experimental and control groups. The experimental group was given knowledge of results by careful and systematic debriefing exercises, while the control group had no post-action critiques. Results clearly favored the experimental group; these two crews showed more improvement in all functions than the control group. An important finding was that those functions which have the "highest visibility" improved most with the control group, while the less visible functions improved markedly in the experimental group having post-exercise discussions. It appears that team members learn from group experiences when the actions of the individuals can be clearly recognized. These findings tend to confirm earlier results of work by Horrocks and his associates on Navy crews (1959, 1960).

A more analytical approach to this problem has been taken by Glaser, Klaus, and Egerman (1962). From their "molar" approach, the team is considered as a single organism which exhibits the typical phenomena of individual learning. Team performance can be accounted for in terms of the amount of individual reinforcement provided each member from the reinforcement given to total team products. Suggestive conclusions concern the kind of reinforcement the individual can derive from knowledge of results of total team performance. Also, more precise indications are offered as to where and how supervisors can provide critical individual reinforcement.

In another laboratory-type study, Rogers, Ford, and Tassone (1961) addressed the important question of the effect of turnover in crew performance. In a simulated air defense problem, the effects were observed of introducing team members with varying degrees of individual and team experience into crews of varying crew experience. Degradation in crew performance or lack of improvement with experience varied with the stage of team experience of the crew and replacement experience. System

performance was degraded and "... the concept of 'skill dilution' could be used to account for the direction and relative magnitude of the effect of turnover ..." on the experimental information-processing system. In this study, no training techniques to overcome this degradation in performance proved to be effective.

DEVELOPMENT OF TEAM TRAINING

In the attempt to develop a program of training for B-52 aircraft pilot-navigator teams, Krumm and Farina (1962) studied existing missions provided by Standardization Boards. Five kinds of criterion measures were constructed, to be used in operational missions and during simulator training. Thirty-eight experimental and 37 control crews participated in the experiment. Small improvements in performances, especially for the navigators, were noted, but from the follow-up data from operational bases early reflections of improvement in experimental groups washed out rapidly.

During the course of the study, Krumm and Farina devoted considerable attention to crew coordinating activities and to categorizing the various kinds of communications on the intercom system. There was some evidence that voluntary inputs by crew members were significant indices of crew coordination. This effort to discover some important intervening variables in crew coordination is significant in the attempt, if not in the actual finding.

Development of indoor training exercises for the Armored Reconnaissance Platoon is under way at the HumRRO Unit at Fort Knox. Following a survey of activities of platoon members (Cook, 1963), a training exercise employing a map terrain display and requiring appropriate decisions by key platoon members is under development. The armored cavalry platoon is unique in Army organization in that coordination between armor, infantry, and heavy mortar crews is required within the same platoon.

Team training of infantrymen offers some unique problems, since these teams have no large weapon or piece of equipment which defines their job duties. Toward the development of team effectiveness, George (1962) has proposed three kinds of manipulations designed to induce team effectiveness. First, there is the use of team training in situations designed to develop and reinforce the habit of coordinate behavior; the hypothesis is that such a habit will carry across situations and across groups. Second, there is the possibility of increasing resistance to high activation by exposing the team to gradual increases in pressure and suitable variation of the "central person" in the group. Finally, experimental training which enhances the task orientation of the position of formal leadership can be designed to increase the amount of task orientation in group code.

This work is now under way in a series of five experiments, one of which has been reported (George, Hoak, and Boutwell, 1963). Evidence has been accumulated that the conditions of training can be so arranged as to require teamwork among members of four-man rifle teams which will produce some 20% improvement on criterion problems. The criterion problems involve team firing on an advancing series of pop-up targets by the team as a whole; experimental treatments involve other kinds of team problems. Evidence from these experiments indicates that necessary characteristics of effective team training include the following demands:

(1) A minimum performance level must be required of the team as a whole.
(2) Teamwork--that, sharing of work, compensating for each other--must occur to attain minimum criterion standards.
(3) Team training must not be allowed to stop until criterion is reached.

During these experiments, increases in attitudes favorable to teamwork were shown to increase as team output went up, suggesting that it is possible to engender positive attitudes toward team performance and cooperation which will go with the individual as he joins new teams. One further aspect of this work is being reported at this convention (McRae, 1964). Evidence is presented for the development of a positive relationship between task-specific verbal team interaction and improvement in team performance, but no relation has been found with team interaction of an organizational nature.

CONCLUDING REMARKS

In assessing the current state of research and development on leadership, command, and team training, I would make the following observations:

1. Considerable gain in the effectiveness of leadership training has resulted from studies of what specific leadership acts are related to good team performance.

2. Training which allows for student participation in leadership activity is proving to be effective.

3. Instruction in the more impersonal duties of command has been enhanced through exhaustive studies of job responsibilities.

4. Team training has been projected from studies which have specified the roles to be played by each team member in the small military group.

5. The use of simulated situation training is becoming more sophisticated, and has provided means of analytic observations of behavior within teams.

6. The nature of the kinds of individual behaviors on which teamwork depends, and means for developing these, is becoming more fully understood.

7. Techniques are becoming available to develop positive attitudes of individuals toward teamwork.

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CHAPTER 6

GORDON ECKSTRAND

CURRENT STATUS OF THE TECHNOLOGY OF TRAINING

Purpose. The purposes of this paper are to present a brief overview of the current status of the technology of training and to indicate some areas where further improvements would make major contributions to training efficiency. The technology of training refers to a body of systematic knowledge and techniques which supports the design of training systems. It is the technology which bears on the things a training institution characteristically does in setting up and managing a training program to produce men capable of "performing effectively".

General Status of Training Technology. Let me begin by simply stating that a substantial technology of training does exist. The past decade has seen the development of a body of knowledge and technique which is rather directly applicable to the practical problems involved in designing training systems. It is by no means as well developed yet as the technology of aptitude testing; nevertheless, it is still substantial and it is growing.

Both research on training and actual experience in training development contribute to this gradually developing technology. In fact, it might be said that something like a psychology of training is developing which is separate and distinct from a psychology of learning: separate and distinct in terms of the goals, hypotheses, methods of investigation, and criteria by which its development is measured. Certainly, it is true that through the years there has been a hiatus between learning research and training practice. It appears that this gap is beginning to be filled, and that a psychology of training is providing the active research and development needed to bridge the gap between basic science and practical technology.

Let me now briefly mention two aspects of training technology which characterize its state of maturity in a general way. One, most noteworthy, is the current emphasis on a systems approach to training. In this approach, the development of a training program is likened to the development of a weapon system. The systems engineer begins with an operational requirement: a precise statement of the objective to be achieved by the system. The systems designer then works backward from these objectives to produce an arrangement of subsystems which, when operated according to some operational plan, will fulfill the objectives. The process ends with a series of tests to assure that the design

achieved does in fact fulfill the requirement. The design of a training system can proceed in the same manner. The behavior which some particular class of military men must exhibit on the job becomes the objective which must be achieved by the training system. The job of the training designer, then, is to select and sequence a series of learning experiences which will produce the required behavior. A testing phase is required to assure that the training program designed succeeds in producing men capable of performing as specified.

Figure 1 (adapted from Hoehn and McClure, 22) shows the processes involved. The first process is the definition of the training objectives or desired performance outcomes. These objectives not only provide the critical input to the derivation of training content but are basic to the development of the criterion measures required to test the training system. The selection of training content, in turn, provides inputs to the design of training methods and materials. The training methods and materials, when implemented according to some administrative training plan, become the training program. At the completion of the training program, criterion measures are applied to obtain indications of the adequacy of the program outputs. The dotted lines show the various feedback loops that are used to modify the training system if the desired output has not been achieved. This general systems approach to training is having an increasing impact on the development of our understanding and control of the training process.

A second aspect of current training technology which characterizes its maturity is the rather considerable literature which has been produced describing this technology. Many books and reports have been published since 1960 which provide excellent summaries of the status of our knowledge in the various areas relevant to a technology of training. They are indicative not only of the growing body of applicable knowledge which exists but of the growing number of psychologists actively engaged in training research and development.

Elements of a Technology of Training. The next sections of this paper are organized around a general conception of the training system, following the basic idea presented in Figure 1. For purposes of this discussion, the processes involved in designing a training system are arbitrarily organized into the following three areas:

1. Determining Training Requirements

2. Developing the Training Environment

3. Measuring the Results of Training

In each area, an attempt will be made to summarize and evaluate the adequacy of our technology. This is not to imply that this technology is being applied to the development of all military training programs. This is definitely not the case. My purpose is to sketch out the status of the technology that is available for application, and I will not attempt to evaluate the extent to which it is being applied.

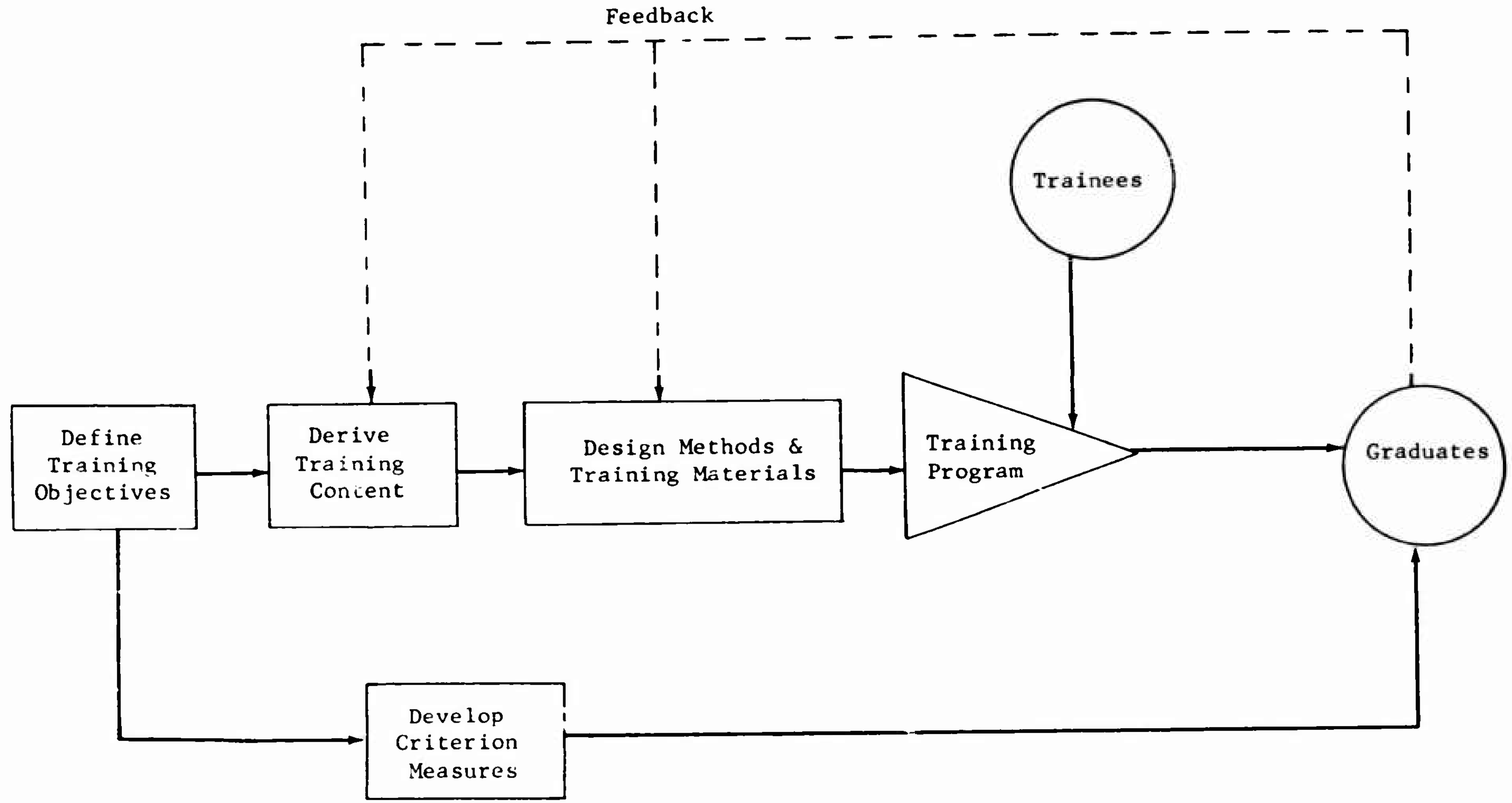

Figure 1. A Systems Approach to Training

DETERMINING TRAINING REQUIREMENTS

EMPHASIS ON TRAINING OBJECTIVES

Fundamental to the design of a training program and supporting materials is the determination of the behaviors to be trained. The behaviors to be trained are those required for successful performance on the job. It is the determination of behaviors which provides the starting point for the design of the training system and for the design of the criterion measures which will be used to evaluate the training system. Certainly, one of the most significant recent developments in training technology is the emphasis placed on the precise statement of training objectives and on the development of methods for accomplishing this task. In fact, Crawford has suggested that this may constitute the single most important contribution which has been made to the design of training systems (6).

Perhaps the above sounds like a statement of the obvious. If so, one should recall that the description of job requirements in behavioral terms is certainly not the starting point for all efforts to develop training programs. Many such efforts still begin with consideration of what is known in a general area rather than what the trainees must know in order to do their job.

STEPS IN DERIVING TRAINING OBJECTIVES

Current knowledge is not yet at the point where the concepts and techniques for determining objective training requirements can be precisely specified. Nevertheless, principles and procedures have been developed and tested which provide a systematic approach to this aspect of training design. Several recent summaries of this material are available (22, 32, 33, 51). While some differences in nomenclature and detail exist among the various approaches available, the major steps involved in determining training requirements can be summarized as follows:

Analysis of the job. An analysis of a job for purposes of training must begin with a listing of all of the tasks which comprise the job. A task may be defined as any group of activities performed at about the same time or in close sequence, and having a common work objective. A position or job, of course, is the sum total of tasks a single person may be responsible for.

Once tasks have been identified, task descriptions must be prepared. Task descriptions specify the essential activities involved in the performance of a task. They describe the activities of the human being in operational terms, i.e., terms which are characteristic of, and appropriate to, the system. Usually included in task descriptions are the purpose of the activity, the equipment involved, the conditions

under which the activities are performed, and criteria which define adequate performance in terms of time, errors, probability, etc. These task descriptions form the basis for job descriptions which are essentially a specification of job performance requirements. They specify what a man must be able to do to be considered satisfactory on his job. Miller has defined a good task description as "one which specifies what criterion responses should be made to what task stimuli and under what range of conditions" (32).

Specification of knowledge and skills. The next step is to select the concepts, skills, information, etc., which trainees must be taught to enable them to meet the performance requirements specified in the job description. This is the process of determining the means by which the job performance requirements can be achieved. This process of determining knowledge and skill requirements is a complex and difficult one, and we are far from being able to specify an optimum procedure to accomplish it (20). We do know, however, that the process is aided by looking at job performance requirements in behavioral rather than operational terms. The techniques of task analysis have been developed and refined over the past decade for this purpose. Task analysis is a systematic method for determining the behavioral requirements in task performance, and a number of procedures and formats for this purpose have been developed and used. The training designer must use the task analysis to determine what the trainee should be taught in order to perform effectively on the job. Many criteria will assist him in making these decisions, but task analysis essentially remains a process that is highly subjective and based considerably upon experience. Any major improvements in this area are dependent upon the development of a taxonomy which will provide the task analyst with terms and concepts useful in looking at tasks in terms of their behavioral ingredients.

Determination of training objectives. Based upon the specification of knowledges and skills which are required to meet job performance standards, the objectives of training are formulated. Referring back to our systems model, these objectives are essentially specifications which define the output expected from the training system. The clarity and adequacy with which this can be accomplished is primarily dependent upon the completeness and accuracy of the determination of knowledge and skill requirements. A well formulated set of training objectives must meet at least the following general criteria:

1. Relevance - Is each training objective defensible in terms of the knowledge and skill required for adequate job performance?

2. Completeness - Do the objectives account for all of the required performance outputs?

3. Measurability - Are the objectives stated in a way which suggests an operation for determining that the objective has been achieved?

The previous paragraphs have been written as if the particular training system being designed was the sole means for developing the required performance output. This is an obvious oversimplification. Training objectives are not necessarily the same as job performance requirements. In fact, they rarely are. Training is almost always divided into certain stages (basic, individual, team, etc.). The objectives of any one course or stage of training are, consequently, usually something less than the complete job performance requirements. Likewise, some training is almost always left to be completed in the actual job context. The achievement of certain performance capabilities may be assigned to various types of job aids. Therefore, even the final stage of training may have training objectives that differ from the job performance standards. Thus, the overall training objectives which are to be accomplished by any particular training system must be broken down into a series of sub-objectives. In terms of a technology of training, it is important that the process start with an analysis of what the trainee will be expected to do on the job. However far the process of fractionation is carried, the process remains rooted in job performance.

SUMMARY

In summary, what can be said about the status of our knowledge on determining training requirements? Briefly this. We can specify a series of steps that one should follow, and there is reason to believe that these steps have considerable generality. A number of tested formats and procedures are available which are useful in carrying out these steps, and criteria are available for evaluating the results. Nevertheless, the gathering, classifying and organizing of information about training requirements is still s judgmental process depending to a considerable extent upon the experience of the training analyst. The current state-of-the-art does, however, serve to make this judgmental process explicit and systematic.

DEVELOPING THE TRAINING ENVIRONMENT

After the objectives of training have been specified, the next step is to determine how these objectives can best be attained. This involves developing a training environment which will transform inputs to the training system (trainees) into graduates who can perform at specified levels on the job. Here again, the systems design analogy is appropriate. The goals of the training system designer are the required human performance outputs. His task is to design and assemble methods, materials and media which will provide the learning experiences required to achieve the training goals. This can be looked upon as a procedure of selecting or designing training tasks and of establishing the procedures for practice

on these tasks. We see here the two factors that are involved in optimizing training efficiency--transfer of training and learning efficiency. Training tasks are designed to produce transfer, and procedures are selected to assure that these tasks will be learned efficiently. What does the technology of training have to offer in carrying out this process?

APPLICABILITY OF GENERAL PRINCIPLES

An impressive body of information on human learning has been accumulated. One might expect that this body of information would provide systematic and practical guidelines for the training systems designer. As is generally known, I am sure, this is not the case. Attempts to derive from this information principles useful in designing training tasks and procedures have proved to be disappointing. Gagne and Bolles have suggested several reasons why this is true (16).

Despite this state of affairs, some general principles regarding the design of training tasks and procedures of practice appear to have rather wide applicability across different types of training functions. Although such principles are generally only qualitative in nature, they are of considerable assistance in developing efficient training environments, and many existing training programs could be improved by their application. Several recent publications provide useful summaries of these principles (16, 21, 28, 43).

One of the major results of the past decade of military training research has been the recognition of the appropriateness of different training activities for different task characteristics. For example, the training activity appropriate for learning a fixed procedure differs from that appropriate for a problem solving task. Any very precise and specific guidance for designing the training environment will require that principles be differentially related to tasks on which training is required. Hoehn has made a preliminary attempt to do this with respect to electronics maintenance positions (21). It is difficult, however, to organize existing information in this manner. What is lacking is a reliable system for classifying tasks into a set of categories which are homogeneous with respect to the conditions fostering learning. Such a classification should readily encompass both the tasks which are used in the laboratory and those found in military jobs. The availability of such a task taxonomy would be valuable to the technology of training in two major ways. First, it would immediately provide a system for organizing existing information in a way which would facilitate its application to particular training problems. Second, it would provide a most useful tool in determining deficiencies in our knowledge and thereby serve to guide future research. Until such a task classification scheme is available, the differential application of principles in the design of training environments will be difficult and imprecise, having more of the characteristics of an art than a technology. A general discussion of this problem has been provided by Cotterman (5).

One of the major problems in developing an efficient training program is how to divide the total knowledge and skill requirements of a job into segments of training content and how to sequence these segments. This is a problem which is never faced by learning research involving only simple tasks. It is also a problem on which it is difficult to do good applied research due to the sheer magnitude of the task of experimentally comparing alternative ways of organizing a lengthy training program. Consequently, little is available in the way of experimental data. Miller, however, has developed a general approach for dividing total performance requirements into training segments (31) and Jones has pointed out how molar correlational analysis can be used to determine the best order for a series of training program elements (23).

TRAINING MEDIA

The term training media has come to refer to a class of instructional aids and devices that vary from training films through complex simulators. Military training psychologists have devoted a great deal of their effort to studies of various kinds of training media as opposed to training methods. There are perhaps two reasons for this.

First, training aids and devices are widely used in military training. The complexity of the jobs involved and the requirement for training efficiency has led to an increasing emphasis on technological aids for training. In the development of any particular training program, one of the most important decisions that must be made concerns the media through which instruction is to be presented.

Second, military psychologists have perhaps realized that it is easier to implement principles of effective training when they are embodied in devices and other media that provide reproducible blocks of instruction than when an attempt is made to influence the behavior of instructors. Travers has used this argument in suggesting that behavioral scientists will have the greatest impact on training if they concentrate on equipment and devices (47). Likewise, the fact that media can be used over and over again is an important factor in allocating resources to their improvement.

A great deal of research has been devoted to the various kinds of instructional media. For most of the media, data are available concerning at least some of the factors which determine their effectiveness. Several recent treatments of this information are available (10, 26, 27). Likewise, a good start has been made on organizing information on the effectiveness of various training media in meeting specific training objectives. Here also, publications are available which provide guidance for determining when media are most suitable (7, 37).

SIMULATORS

With the increased complexity of the weapon and supporting systems being developed for use by the military, greater dependence is being placed upon simulators for training the individuals and crews who must operate these systems in an extremely accurate and reliable manner. Because of their importance and expense, training psychologists have devoted considerable attention to the design of simulators, and several summaries of the available information have been published (1, 15, 35, 43). Nevertheless, engineering technology related to simulation has grown much more rapidly than has our ability to specify the characteristics which a simulator should have in order to be most effective. Consequently, most current simulators are designed against a criterion of physical fidelity rather than fidelity of the operations and tasks which are presented to the trainee. In many cases, of course, this is not a problem, since physical fidelity often does produce high transfer of training and costs no more than some conditions of lesser fidelity. In other cases, such as visual simulation and motion simulation, physical fidelity is difficult, costly or impossible. In these areas, we are badly in need of additional research. Yet, such research is costly, time consuming, and poses difficult methodological problems.

AUTOMATED INSTRUCTION AND PROGRAMMED LEARNING

No current summary of the technology of developing training environments would be complete without some mention of automated instruction and programmed learning. These techniques have received a great amount of attention and have influenced many basic concepts of training. Basically, these are techniques to achieve greater control of learning with minimum use of an instructor. Usually, automated instruction and programmed learning involve the presentation of a relatively small amount of instruction, either an overt or an implicit response by the trainee, and some indication of the adequacy of the trainee's response. The techniques--essentially practicing relevant behaviors--represent an application of the principles of reinforcement and learning. Although most devices and programs are based on similar principles, a wide variety of devices and programs have been developed. Publications are available which provide practical summaries of the types of devices and programs that are available (19, 25, 38), how to prepare such instructional materials (29, 46, 48), and the potential uses of such instruction (17).

Military research and applications have contributed very extensively to the technology of automated instruction and programmed learning. Military organizations conducted much of the applied research that led to these techniques and have actively promoted their use (36). Hopefully, these techniques will ease some of the military training problems associated with individual differences among trainees, inadequate number or quality of instructors, need for personnel trained above a minimum level but preferably quite uniform in performance capability, and training programs of fluctuating magnitude (9).

Evaluations of automated instruction and programmed learning have revealed a wide range of findings. Perhaps the safest conclusion is that the techniques can be applied to a wide range of training problems with a substantial improvement of one type or another (36, 39).

Future training systems undoubtedly will involve greater use of automated instruction and programmed learning. These techniques may well be mixed with more conventional media. Judging from the bulk of many self-instructional programs, and the exploding engineering technology, we can expect future self-instructional systems to involve super-reduced film and/or computers. Such systems offer a necessary potential for the storage and retrieval of instructional information.

The general concept of self-instruction has extensive implications for the technology of developing the training environment. Impressive results have been obtained by allowing trainees to select their training environment from a variety of offered materials. In an early study on this concept, trainees were given the training objectives and allowed to select the media to reach the objectives. The trainees offered this opportunity reached the training objective more rapidly than those trained in any other way. This concept of learner-controlled instruction has great potential and should receive increasing research attention.

SUMMARY

In summary, it can be said that much of the research on human learning provides little guidance on practical training problems. Still, a number of useful principles are available. Some of these have wide generality while others appear to apply only to training for specific kinds of tasks. A major advance in the development of efficient training environments would be possible if a classification of training tasks could be developed which would relate task characteristics to principles of effective training.

A substantial body of knowledge is available about the effectiveness characteristics of various training media, and guidance is available for selecting media for various training functions. Simulators are being used increasingly to provide high level training for complex man-machine systems. Our ability to specify the characteristics which such devices should have has not kept pace with engineering technology.

Automated instruction and programmed learning appear to be effective means of meeting many training objectives. These techniques are here to stay and are having considerable impact on both older and new training techniques. Although the printing press is far from being outmoded, film and computer techniques may promise economical and efficient learner controlled instruction in the near future.

MEASURING THE RESULTS OF TRAINING

Proficiency measures during training can serve a number of different purposes. This paper is primarily concerned with proficiency measures whose major purpose is that of quality control; i.e., evaluating the training program in terms of the goals which have been set for it. In assessing the current status of technology in this area, two major trends should be mentioned.

EMPHASIS ON EVALUATION

In recent years, there has been an increasing awareness of the need to evaluate training programs. Trainees have always been tested, of course, but the purpose has frequently been to assign grades rather than to evaluate the training program. Several factors have contributed to this change in emphasis. One is simply the greater urgency for training efficiency in the modern military organization faced with limited manpower resources and equipment of increasing complexity. Another is the use of the systems approach to the development of training systems. Application of the systems approach is dependent upon various feedback loops which can be implemented only by measuring the output of the training system.

The high level of current interest in proficiency tests for training evaluation is indicated in several recent treatments of this problem in the literature (14, 18, 42, 50).

CRITERION-REFERENCED MEASURES

The second major trend concerns the manner in which the training system is to be evaluated. Increasing emphasis is being placed on evaluating training systems in terms of objectives which have been carefully derived from an analysis of the job for which training is being provided. Such proficiency tests are based on the statement of training objectives and should be prepared quite independently from the design of the training program (see Figure 1). If the training objectives have been carefully derived and state what the graduate should be able to do, under what conditions, and to what standard of proficiency, they provide a useful criterion for evaluating the training program.

Proficiency measures which rank individuals with respect to such an absolute standard of quality are called <u>criterion-referenced</u> measures. They permit assessment of performance and provide information on degree of competence which is independent of the performance of others. Such measures are useful in quality control, in that they permit one to determine whether an individual has reached or surpassed performance standards that have been established.

Many of the proficiency measures currently used in training systems are norm-referenced. With such measures, a particular individual's proficiency is evaluated in terms of a comparison between his performance and the performance of other members of the group. Norm-referenced measures tell us only that one individual is more or less proficient than another, but tell us little about how proficient either of them is with respect to the performance standards. For this reason, such measures are of limited value in proficiency measurement intended for quality control.

This is unfortunate, because most of the research which has been done on psychological testing has been concerned with norm-referenced measures. However, the two types of tests are quite different, and it is important that the technology appropriate to one is clearly distinguished from the technology appropriate to the other. An excellent discussion of the important differences between criterion-referenced and norm-referenced measures is provided by Glaser and Klaus (18).

DEVELOPING PROFICIENCY MEASURES

One of the major problems in the development of proficiency measures is the specification of the behavior to be measured. If the approach to training system design described here has been followed, this step will already have been accomplished with the development of the training objectives. For most military jobs, these training objectives will be stated in terms of job performance standards. Proficiency measurement then becomes the task of measuring how well the trainees can meet these job performance standards. Unfortunately, relatively little attention has been paid to the problem of measuring how well an individual can perform the tasks for which he has been trained. In contrast, the literature on written tests is quite substantial. There is, however, an increasing recognition of the need for proficiency tests which measure the individual's ability to perform specified tasks at criterion levels, and it is expected that this is one problem which will receive increased attention in the future.

There are three important classes of problems that must be faced in developing proficiency measures. These will be discussed briefly below in terms of the current state-of-the-art.

Measurement problems. Any proficiency test is an attempt to measure human behavior. As such, a number of basic problems in psychological measurement are involved--problems such as reliability, testing conditions, test formats, etc. Much has been written on these aspects of the measurement problem, and, in general, the technology is well developed. Adequate treatments of this technology are available and no further discussion is required here.

Relevance. The most basic problem in developing proficiency measures for training is relevance. The problem of relevance is one of establishing the degree of behavioral equivalence between the test situation and some other situation, usually performance on the job. Developing proficiency measures consists of developing test situations which will elicit trainee behavior which is closely related to that required for successful performance on the job. In accomplishing this, a variety of measurement approaches are available.

The most direct measure of proficiency is to test the trainee's ability to perform on the job. Such measures are often used both in industry and in the military. Wilson has listed five categories of on-the-job measures which have been used (50):

1. Tangible product measures
2. Measures of specific behavior elements
3. Gross performance measures
4. Inferred positive performance
5. Malperformance measures

Tangible product measures are not very useful in military operations because a product in this sense is seldom involved. Methods 3, 4, and 5 all have the serious disadvantage for use in evaluating training in that they are really measures of systems performance rather than of human performance. Thus, it is impossible to obtain a measure of trainee performance independent of other factors which also influence system output. Examples of such factors are equipment variability, adequacy of supervision, adequacy of logistic support, etc. Measures of specific behavior elements on the job, however, have often proved to be both feasible and useful. With this method, jobs or tasks are broken down into individual, quite specific activities. The performance of these activities is then observed on the job. When this method is used with carefully prepared checklists and objective standards of performance, it can be quite reliable and useful in evaluating training. A recent example of the use of this method to evaluate training has been reported by Siegel, Schultz and Federman (40). It would appear that this type of on-the-job measure deserves considerably more attention.

A second approach to the problem is the use of simulators or other types of work sample situations. Increasing sophistication and ingenuity in techniques for simulation are providing new ways to elicit criterion behavior for proficiency measurement. Tests using simulation of the work environment offer many of the advantages of on-the-job measures. At the same time, the greater control which simulation allows makes it possible to rule out many extraneous factors which exist on the job. With the growing need for more intensive and specific measures of job performance, simulators will become increasingly important in the proficiency measurement field. Considerable attention has already been given to the use of electronic simulators in providing improved opportunities for measuring human performance in complex man-machine systems. Such simulators

reproduce all of the major sources of stimulus input and also allow for realistic response output. In addition, the computer portions of such simulators can often be used not only to provide the dynamics required for system simulation but to monitor and score automatically the performance of the trainee. The status of the technology involved in using simulators to measure the proficiency of flight crews has recently been documented by Smode, Gruber, and Ely (42). This treatment would apply, in general, to any complex man-machine system. Some jobs do not involve extensive interactions between man and machine, of course, and in such cases, it is often possible to elicit criterion behavior without the use of complex equipment. Two recent examples of such job simulations are the in-basket test for school principals (13) and a classroom simulation for teachers (24).

Situations do exist and will continue to arise where it is difficult or impossible to obtain objective measures of performance. In such cases, one must be content to use tests which measure correlated behaviors. Such tests elicit and evaluate behavior which is different from that which is required on the job, but which is expected to be correlated with job performance. The most common type of correlated behavior measures is the use of verbal tests to assess performance which is essentially non-verbal. The many job knowledge tests used by the military services are examples of this approach. Such tests have the advantage of being easily constructed and economically administered when compared with on-the-job or simulated proficiency measures. However, whereas proficiency measures made on the job or in simulated situations can be said to be relevant by definition, this is not the case with correlated-behavior measures. With such measrues, relevance must be established empirically, e.g., correlationally, with performance-derived scores. Once this has been done, their use is perfectly defensible. Techniques for developing and validating written tests are, of course, well developed. It is quite likely that the optimum proficiency measurement test for many situations lies somewhere between complete simulation and written tests. At the present time, however, few principles exist for deciding what features of the job environment must be simulated for proficiency test purposes. This is a most important problem area and requires additional research.

Sampling. A third important problem area in developing proficiency measures is that of sampling. The content of a proficiency test used to evaluate training must accurately reflect the objectives of training, and the extent to which it does is a measure of its content validity. In some highly repetitive jobs, it is possible to obtain proficiency measures on the total universe of job behaviors. In most military jobs the variety of component tasks involved and the range of conditions under which they must be performed make this approach impossible. In these cases, it is necessary to sample in some way, usually by selecting for measurement those behaviors judged to be most important in successful performance on the job. Techniques in the area of sampling and the closely related problem of weighting are not well developed, and the most commonly employed method is that depending upon the judgment of experts.

An excellent discussion of sampling and weighting in the development of proficiency tests is provided by Glaser and Klaus (18).

Even with sampling, proficiency tests based upon measuring performance either on the job or in simulated situations often involve excessive amounts of time. In measuring the performance of maintenance personnel, for example, a single troubleshooting problem may run several hours--one of the major reasons why written tests have been so much more popular than performance tests. It would appear that there is a need for the development of new concepts in this area. The present dilemma of excessive testing time is closely tied to the concept of grading students for the purpose of ranking them. If one accepts the fact that proficiency measures at the end of training are for the purpose of evaluating the training system rather than for ranking students, other strategies may be possible which will permit adequate evaluation in much less time.

SUMMARY

In summary, it can be said that greater attention is being given to the evaluation of training systems in terms of proficiency tests which are criterion-referenced. Developing such proficiency tests involves problems in three areas--measurement, relevance, and sampling. A rather well developed technology is available to support the development of tests which satisfy basic measurement criteria. Relevance can be assured by measuring proficiency on the job or in simulated job situations or by measuring behavior which has been shown to correlate with proficiency on the job. It would appear that proficiency measures taken of simulated job performance offer the most promise, but more information is needed on how to specify the degree of simulation required to assure relevance. Techniques for sampling behavior to include in proficiency tests are not well developed. New concepts are required to reduce the time which performance tests require.

PROMISING RESEARCH AREAS

The previous sections of this paper have discussed the status of the technology which bears on training the military man to perform effectively. It has been seen that a considerable body of systematic knowledge and techniques does exist, and that it is growing rapidly. We have by no means reached the decelerating portion of the curve, and future research and development may be expected to produce substantial gains in training efficiency. What are some of the areas in which further improvements would make major contributions to the training of military personnel? A general discussion of new ideas, techniques, and procedures in the field of training and training research has been provided by Smode (41). My purpose here is to single out for brief discussion several areas which appear to be especially promising. Before

doing this, it would be well to mention again that information which is available is not being applied in many areas of military training. Significant, and in some cases, large, improvements in training efficiency could be achieved by using what we already know. Therefore, it would appear that a study of the problems and processes of applying the currently available technology would have high potential payoff.

TASK CLASSIFICATION

The earlier portions of this paper have made clear the basic importance of a task taxonomy to the development of training systems. No rigorous science of behavior in instructional situations will be possible until we have made much more headway on the problem of classifying the tasks on which instruction is given. What is needed is a task classification scheme such that membership in a class will be related to the applicability of principles of training. The availability of such a classification system would be a major advance in the technology of training. It seems likely that it will be a long time before such a system is available. A note of encouragement is seen, however, in the increased interest which has been demonstrated in this problem during the past few years. A number of tentative classifications applicable to limited areas have been proposed: Fitts (11) for perceptual-motor skills; Miller and Folley (34) and Hoehn (21) for electronic maintenance tasks; and Smode, Gruber, and Ely (43) for operator tasks in weapon systems. Likewise, Fleishman's studies of perceptual-motor learning in terms of the ability requirements of tasks provides a method for task classification (12). An early project directed specifically at this problem resulted in three general classification systems based upon different approaches to the problem. These were presented at the APA Convention in 1960, and two of them have been subsequently published (30, 44). Thus, it is apparent that some interesting progress is being made in this area. What is needed now is a vigorous effort to test and evaluate the available taxonomies in terms of their reliability, validity, and heuristic power. Only then will we know whether we are on the right track or whether entirely new concepts and approaches will be required.

INDIVIDUALIZATION OF TRAINING

The extent to which individual differences in learning characteristics exist sets a limit on the efficiency with which a group of individuals can be trained using any single training procedure. Any further increases in efficiency must be obtained by matching training procedures to the characteristics of the trainees. This problem is the counterpart of the task classification problem. Here, however, we are interested in classifying students with respect to their training characteristics. It seems quite likely that one of the most significant ways in which the efficiency of military training can be increased is greater use of the various devices and techniques which allow instruction

to be individualized. There is some evidence to support this position. In a promising basic research study, Allison found significant relationships between learning parameters and measures of human ability (2). A few other studies have shown a relationship between training methods and aptitude differences. Theoretically, of course, any measurable differences between individuals which affect the efficiency of learning can be used as a basis for the differential programming of instruction. The general implications of this concept for training and training research have been discussed by Eckstrand (8).

Recently, the development of automated teaching devices and techniques has provided a class of teaching and training media which are capable of adaptation to individual differences. However, these devices and techniques have as yet provided only the most limited type of adaptability. This is perhaps not surprising in view of our lack of knowledge about the relationship between individual differences and various methods of programming training. Stolurow has recently described a concept called idiomorphic programming in which the responsiveness of the teaching system is based upon a large amount of information about the individual student (45). The effective implementation of such a system will be impossible, however, until much more information is available. This is certainly an area of research which offers high potential payoff. The importance of this research is highlighted by the rapid advances being made in computer technology and adaptive programming techniques. Electronic computers are making possible training systems with almost unlimited possibilities for responsiveness to individual differences, but we do not yet know how to make use of this potential.

FACTORS OUTSIDE THE TRAINING SYSTEM

As the quantity, variety, and complexity of the equipment used by the military increases, there is an increasing need for methods to reduce the cost and time for developing technically qualified personnel to operate and maintain this equipment. One way to do this is to increase the efficiency of training, and this has been the primary subject of this paper. Another approach is through factors outside the training system itself which have an impact on the nature and magnitude of the training required. It seems likely that major reductions in training costs and time can be achieved by exerting some kind of control over the training requirements generated. Two areas of importance will be mentioned.

Personnel system. The personnel system in the military services has an impact on the training system in several ways. Consider the matter of assignment at the end of training. In a recent Navy survey of Electronic Technicians, it was found that approximately one-half of the ET's serving with the fleet and about one-fourth of those ashore were not working primarily within the area indicated by their service ratings (3). Similar findings have been reported in an Army study (4).

If the personnel system cannot assure that a graduate will be assigned to the job for which he was trained, the training system is required to produce a generalist rather than a specialist. This greatly increases cost and time. Thus, one area which would warrant additional research is the relationship between assignment and rotation procedures and the cost and time required for training.

Equipment design. Training requirements are, to a considerable degree, implicit in the design of the equipment which the military services develop and use. Various techniques are used to predict what training requirements are generated by new equipment so that appropriate training systems can be developed and operated. At the present time, however, very little effort is made to control training requirements by influencing the design of equipment. There is no reason why this should not and could not be done. Certain operational and engineering constraints have been placed on system designers for years, e.g., weight, power, reliability, compatibility with existing facilities, etc. Logically, the same approach could be taken with respect to personnel and training requirements. In order to make this possible we must develop much more quantitative information about the trainability of various kinds of tasks. The availability of such data would make it possible for training requirements to be considered and traded off with other engineering factors in the design of systems. This capability would permit a great improvement in our ability to train military men to perform effectively.

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PART III

PSYCHOPHYSIOLOGICAL FACTORS INFLUENCING MILITARY PERFORMANCE

INTRODUCTION TO PART III

The military, operating in three media, imposes major constraints and stresses on man's sensing, decision-making, and controlling abilities. Assuring maintenance of the individual and continuation of function within a system has required--and continues to require--ingenuity and critical sharpening of research.

Dr. Richard Trumbull, head of the Psychological Sciences Division, Office of Naval Research, planned and organized Part III covering the history and challenge of research relevant to psychophysiological factors influencing military performance.

For Chapter 7, Dr. Trumbull invited the participation of Dr. Earl Alluisi of the University of Louisville, Dr. W. Dean Chiles of the Aerospace Medical Research Laboratories, and Dr. Richard P. Smith of the University of Louisville. This chapter reviews the situational factors likely to occur in the operation of military systems--factors placing atypical demands on the operator in a system--and reports the influence of these factors on individual performance where such influence is known. The review includes discussions of effects of atypical work-rest schedules and schedules for high-alert situations demanding 24-hour operation daily, the interactions of selection and motivation on adaptation to atypical schedules, and some effects of nonlethal chemical incapacitating agencies such as LSD on individual performance.

In Chapter 8, Dr. Randall M. Chambers of the U. S. Naval Air Development Center, University of Pennsylvania, discusses physiological tolerances to G-stimulus variables and the effects of acceleration on a spectrum of human abilities. He bases his treatment of the subject on data obtained on astronauts, pilots, and volunteers during exposure to acceleration environments, and points out that physiological tolerance and performance tolerance may be functionally related but need not be the same, since both are dependent on the criteria of reliable functioning which are accepted.

Dr. Saul B. Sells and Dr. Nurhan Findikyan, both of the Department of Psychology, Texas Christian University, continue the discussion of psychophysiological performance. In Chapter 9, they center their attention on the processes which maintain skills and the processes which impair skills under conditions encountered in both conventional and new military and aerospace activities. While emphasis is on ways and means of mitigation of performance decrement, identification of human tolerance parameters is considered a necessary supplemental task. These authors point out that tolerance, measured in terms of physiological parameters, may be unrelated to performance in various skilled tasks, and that in some cases massive physiological damage can be endured without impairment of certain measured skills. They also caution against unequivocal acceptance of tolerance limits for any variable taken singly as holding for the same variable in complex situations.

CHAPTER 7

EARL A. ALLUISI
W. DEAN CHILES, RICHARD P. SMITH

HUMAN PERFORMANCE IN MILITARY SYSTEMS: SOME SITUATIONAL FACTORS INFLUENCING INDIVIDUAL PERFORMANCE

Among the special characteristics of military systems, especially in times of national emergency, are the atypical demands they make upon the men who operate them. Most of these atypical conditions are situational; i.e., they are the products of sets of circumstances, and they serve to change the working conditions from those designed to be typical to some other set. Thus, they are situational in two senses--they are created by the circumstances of place and time, and they constitute special sets of conditions under which operations must take place. Some of these situational factors, and their influences on individual performance, are discussed in this chapter.

Atypical work-rest schedules. During times of war or other national emergencies, men are often called upon to work atypical schedules. An infantryman does not work merely an 8-hour day and a 5-day week--not, at least, while he is assigned to front-line combat duty. The operator of defensive alerting systems must not work at less than maximum alertness--too much is at stake. In both cases (and the hundreds like them) the situation demands more work than is typical, at higher levels of performance than are typically necessary, with less rest (and, perhaps, less sleep) than is usual, and a cycling of work and rest to which the operator may or may not have previously adjusted.

Yet it is known that man's physiological processes (and to some extent his performances) exhibit variations that are a function of his being adapted to a 24-hour day. When he follows an atypical non 24-hour-cyclical schedule of activities, his physiological rhythms will show some, but not complete, adaptation. Furthermore, persons differ widely in their ability to adapt and in the speed with which their maximum adaptation takes place (Brindley, 1954; Kleitman and Kleitman, 1953).

A recent review of the literature on work-rest cycling (Ray, Martin, and Alluisi, 1960) indicated that within broad limits performance does not appear to vary significantly as a function of the work-rest cycle, provided the work-rest and sleep-wakefulness ratios are held constant and the period of observation does not exceed one week. The exception noted was the decrement in the performance of certain watch-keeping or vigilance tasks that has been commonly observed.

Man is apparently capable of maintaining high-level performances on various tasks while living according to rather rigorous, atypical work-rest schedules, at least for short periods of time. Very few data are available for valid generalizations to longer periods of time, and until recently very few data were available to indicate what might be an optimum work-rest schedule for situations of military importance--i.e., for situations that demand 24-hour-a-day operation, on a high-alert basis, with maximization of the operator's efficiency and reliability, and minimum use of manpower. Data concerning such optimum work-rest scheduling have been collected over the past several years in the Lockheed-Georgia Company's Human Factors Research Laboratory under the contractual support of the 6570th Aerospace Medical Research Laboratories. These data are discussed in the following sections.

Optimum work-rest scheduling. In the earliest of the experimental studies (reported in detail by Adams and Chiles, 1960), the performance of 16 subjects was measured over a period of 96 hours on four different duty-period and rest-period schedules (2 hours of work and 2 hours of rest, 4 work and 4 rest, 6 and 6, and 8 and 8). The subjective reports of the individuals tested suggested that the 2-hour and 4-hour shifts were superior to the others. Because the total period of time studied was relatively brief and the total number of subjects was relatively small, the study probably evidenced low statistical power; it may have been for this reason that the performance differences among the schedules were not statistically significant. It was evident, however, that the subjects could work at the tasks assigned with maintained efficiency for 12 hours per day over periods at least as long as 96 hours.

Two additional 96-hour experiments followed the initial study. These experiments were designed to examine the ability of the subjects to work for greater proportions of the time. During one of these experiments the subjects followed a schedule of 4 hours of work and 2 hours of rest. In the other they followed a schedule of 6 hours of work and 2 hours of rest. Both studies have been reported in full elsewhere (Appendix I, Adams and Chiles, 1961).

The performance data obtained failed to demonstrate the superiority of either the 4-2 or 6-2 schedule of work and rest. But again the evidence obtained from questionnaires completed by the subjects was important; it suggested that severe decrements in performance would probably have resulted from prolongation of the 6-2 schedule beyond the 96 hours of testing. For example, the subjects on the 6-2 schedule averaged less than 4 hours of sleep per day, whereas those on the 4-2 schedule averaged 5.5 or more hours of sleep per day. Unless the circumstances of operation of the system are such as to reduce the sleep requirements of the operator (and, to date, no set of circumstances has been demonstrated to do this), 4 hours of sleep per day over a prolonged period may be considered inadequate (cf. Ray, Martin, and Alluisi, 1960).

These 4-day experiments have been followed by a number of longer term investigations. In the first of these, which we shall call "Operation 360" (Opn-360), two crews of operational personnel from the United States Air Force served as subjects. Each crew was confined to a relatively small (1100 cubic feet) crew compartment and tested on a 4-2 work-rest schedule over a 15-day period (Adams and Chiles, 1961). During this period the subjects had no communication with their normal environment, and communications with the experimenters were limited to intercom messages of direct relevance to the simulated aerospace mission. The 4-2 schedule was selected for early study because it showed promise of being the most efficient, practicable schedule of all the cycles previously studied. When working such a schedule, three men with appropriate cross-training can operate two work stations continuously.

The 15-day period was selected because it extended beyond the point at which individuals can be expected to compensate by extra effort for serious degrees of fatigue-induced stress or deterioration in performance. Also, the choice was influenced by the belief that the subjects would consider 15 days to be a relatively long period of time; they would consider it not a trivial experience, especially if the situation were to have been unpleasant. Practical considerations of economy, and of equipment reliability and maintenance at the time of the study also acted to preclude the use of a longer period of confinement.

Well-marked diurnal rhythms were evidenced in the levels both of performance efficiency and of sympathetic activation. These hourly variations, which equaled or exceeded the variations between daily means in most cases, continued for the full 15-day period of confinement. Wide individual differences were evidenced in the ability to adapt to the 4-2 schedule and to maintain a high level of performance over the 15 days; most subjects showed general drops in performance over the 15 days, but two of them maintained generally steady performance. Also, the performance of a volunteer crew was generally better than the performance of the other which had "volunteered" because it was the only crew available at the time of the study.

Subsequent to the collection of these data, a control study was carried out (Appendix II, Adams and Chiles, 1961). Ten college students served as subjects in the control study. They worked 4 hours per day for 5 consecutive days per week over a period of 6 weeks on the same tasks, and in the same crew compartments used by the experimental groups. Of course, they were confined to the crew compartment only during the 4 hours of work on each day.

The trends in the performance of the confined subjects as compared with those of the control group led to the conclusion that with a minimum of selection, subjects could be found whose motivation and abilities would lead to acceptable levels of performance on a schedule of 4-hours work and 2-hours rest for periods of at least as long as 15 days.

Subsequent to the Opn-360 study, the task battery was extended to include group-dependent performances as well as individual performances. That is to say, two group-performance tasks were developed and tested (Alluisi, Hall, and Chiles, 1962). After further modifications they were incorporated in the battery. In each of the tasks, successful performance required interactions among crewmembers in the form of exchanges of information, cooperation, and coordination. Both provided quantitative indices of crew performance.

In the first of two subsequent long-term confinement studies (HOPE-II), six Air Force Academy Cadets followed a schedule of 4 hours work and 2 hours rest for 15 days. These six subjects manned four work stations continuously on a 24-hour-a-day basis. In HOPE-III, the second of these two studies, 10 USAF Pilots manned five work stations continuously for a 30-day period; the pilots were organized into two 5-man crews that worked alternating 4-hour shifts. (Both studies have been reported in full by Alluisi, Chiles, Hall, and Hawkes, 1963.)

During the entire 15-day (HOPE-II) and 30-day (HOPE-III) experimental periods, the groups were confined to the 1100-cubic-feet volume of the advanced-system crew-compartment mockup used in the previous studies. While on-duty, each subject performed on 6 tasks (arithmetic computations, auditory vigilance, warning-lights monitoring, target identifications, probability monitoring, and code-lock solving). The tasks were displayed on operator panels located in the work-station area of the crew compartment.

The previous conclusion with respect to the 4-2 schedule was supported; namely, with a relative minimum of selection, highly motivated subjects can be found who can maintain acceptable performance levels on a schedule of 4 hours on-duty and 2 hours off for a period of at least 2 weeks duration, and probably for a month. On the other hand, performance was generally better sustained by the crewmembers who followed the schedule of 4 hours on-duty and 4 hours off, and it was maintained for the entire 30-day period of their confinement. It was concluded that during actual missions, the 4-4 schedule can probably be followed for 60 or 90 days without decrements in performance.

Because of this, and because the 4-4 schedule permits a certain safety factor (crewmembers can make up for an illness or other loss of man-hours by following a 4-2 schedule when necessary), the 4-4 work-rest schedule was recommended as feasible for use over moderately long intervals of time where high-alert performances are required on an around-the-clock basis, and where total manpower is to be minimized. In short, the 4-4 work-rest schedule appears to be an optimum schedule under the requirements noted and with the criteria used.

<u>Adaptation, motivation, and selection</u>. In the three long-term studies summarized in the preceding section (Opn-360, HOPE-II, and HOPE-III), evidence was obtained to show something of the importance

of motivation and selection in relation to the maintenance of high-level performance while working the demanding schedules used. It has been noted that in Opn-360 the volunteer crew performed better on the average than the crew which "was volunteered." It has been noted also that in the same study individual differences in adaptability were wide. It was the experimenters' judgments, prior to seeing the summarized data, that two of the subjects would score better on all tasks than the other subjects because they appeared to be more highly motivated--they appeared to be trying harder. These two subjects did in fact show generally stable performance with little or no decrements over the 15-day confinement period, and they were the only two subjects in Opn-360 who showed no general decrements.

There were three major differences between the Opn-360 study and the HOPE-II and HOPE-III studies, and these differences relate to the motivation of the subjects. First, in the latter two studies, the subjects were required to perform two group-tasks, whereas such tasks were not contained in the battery used in the earlier Opn-360 study. Whatever the effect of group interaction (we suspect it serves a social-incentive, alerting function), it was a requirement placed on the subjects of HOPE-II and HOPE-III, whereas it was only incidential in Opn-360.

Secondly, each subject volunteered as an individual to serve in HOPE-II and HOPE-III, presumably without the kind of social-pressure phenomena that might have existed in the regularly constituted groups that were being asked to volunteer as units to serve in Opn-360. In addition, the HOPE-II and III subjects reported that they viewed their participation as being of some value to their potential careers as aerospace vehicle operators.

Finally, the HOPE-II and HOPE-III subjects were asked to attempt to minimize the previously demonstrated diurnal performance effects. (Of course, we have ignored in this listing the principal difference in the work-rest schedules--4-2 for Opn-360 and HOPE-II, and 4-4 for HOPE-III.)

The performance of the individual subject in these studies was evaluated as follows: A rank-order coefficient of correlation was computed between each of the performance measures of each of the subjects and the days of confinement; thus, a positive coefficient (rho) represented performance that improved with time, and a negative rho represented performance that deteriorated with time.

Of all the rho's that were computed, approximately 2/3 were statistically significant in each of the three studies. Of these significant trends (1) 90% were negative and 10% positive in Opn-360, (2) 72% were negative and 28% positive in HOPE-II, and (3) 8% were negative and 92% positive in HOPE-III. We believe these percentages may be taken as an indication of the order of magnitude of the essential differences

that might be expected on the basis of motivation and selection (in the case of Opn-360 versus HOPE-II, or on the basis of the scheduling of work and rest (HOPE-II versus HOPE-III).

Finally, the diurnal variations in performance that were so striking in the data of Opn-360, and that appeared to be highly correlated with the diurnal variations in physiological activation, were not obtained in HOPE-II and were greatly reduced in HOPE-III. Apparently man can be motivated and educated to avoid the diurnal variations in performance--but only to an extent. In both HOPE-II and HOPE-III diurnal rhythms were evidenced in the data on body temperature and heart rate, as well as in the performances obtained under conditions of performance stress. That is to say, when the operator was overloaded, the diurnal cycling re-appeared in the performance data.

Thus, "Channel Capacity" can be taken as a limit beyond which motivation cannot push; since we seldom work at full channel capacity, even in military systems, this does not seriously limit our generalization that the degree of adaptation to situational factors will be influenced greatly by motivation. Of course, it will also be influenced by selection, to the extent that the men selected are either (1) better able to adapt to the specific situations or (2) more highly motivated to adapt.

Performance reserves and the measurement of situational stresses. The data of the preceding sections can be interpreted as suggesting that man typically has performance reserves upon which he can call when faced with situational stresses, if he is sufficiently well motivated to do so. If this is true, then the degree of stress imposed by the situation cannot always be measured simply in terms of the levels of performance obtained--these latter also being functions of the operators' motivational levels and of their performance reserves. Instead, the first stress can be evaluated at times only indirectly, for example, by measuring performance when a second stress imposes demands that can be met only by use of already depleted performance reserves.

That is to say, our normally assigned duties do not typically push us to any physiological or psychological limits, and when sufficiently well motivated we are remarkably able to maintain high performance levels, at least for short periods of time, even under quite stressful conditions. The costs of maintaining performance might well be evaluated in terms of an associated reduction in performance reserves; indeed, this might be used as a measure of the degree of stress imposed. Thus, whereas a 16-hour work period per day may not show gross deteriorations in performance over a 2-week period relative to the performances obtained with 12-hour work periods, those persons who have been following the more stressful schedule might be less able to meet additional demands (such as a 24-hour period of continuous work) than those who have been following the less stressful schedule even for only a short period. Results of recently completed experimentation (Alluisi, Chiles, and Hall, 1964) appear to support this view.

These four additional studies investigated the relative performance reserves of subjects following the 4-2 as compared to the 4-4 work-rest schedules. An indication of the performance reserve was obtained by investigating the impact on performance of a period of sleep loss. Specifically, midway in a 12-day confinement period (days 6 and 7) subjects on the 4-2 schedule went 40 hours without sleep and subjects on the 4-4 schedule went 44 hours without sleep. In both cases the subjects essentially worked continuously throughout the sleep-loss period; they worked their normal 4-hour on-duty tours, and then performed additional "auxiliary" duties during what had normally been their 2-hour or 4-hour off-duty periods.

On the day before the beginning of the sleep-loss period, day 5, the performance of the subjects on the 4-4 schedule was superior to that of the subjects on the 4-2 schedule. This is as expected on the basis of the data reported in the previous sections. Furthermore, as expected on the basis of other experience with sleep-loss stress, the performance of the subjects on both schedules at the end of the sleep-loss period (actually during the second day without sleep) was significantly poorer than on the day prior to the beginning of sleep loss.

The findings of greater importance, however, were those related to the differences between the two schedules: The subjects on the 4-2 schedule showed a greater decrement in performance as a result of going without 40 hours of sleep than did those on the 4-4 schedule (who went without 44 hours of sleep). This difference was significant only for those tasks that appeared to require close concentration (arithmetic and probability monitoring), even though concentration had to be sustained for only very brief periods of time--i.e., on the order of seconds.

As to the length of time required for recovery from the adverse effects of the sleep-loss periods, the data indicated that the subjects who followed the 4-4 schedule returned essentially to their pre-sleep-loss performance levels within 12 hours (two, 4 hour sleep periods) following the period of sleep loss. On the other hand, the subjects on the 4-2 schedule regained the levels of performance predicted for them within 14 hours (or three, 2 hour sleep periods) following the period of sleep loss ("recovery" for these subjects could not be taken to mean the same levels as attained prior to the sleep-loss period since the previous study of this 4-2 schedule had indicated that general performance decrements would take place over time).

In general, the results appear to indicate that the performance reserves of subjects following the 4-2 schedule are significantly poorer than those of subjects following the 4-4 schedule, and, therefore, that the 4-2 schedule may be regarded as overall more stressful to man than the 4-4 work-rest schedule.

Influence of the type of task. Situational factors, such as the assignment of an atypical work-rest schedule, may be expected to have

different effects on different operations. Likewise, different conclusions may be reached in separate studies of these factors if different tasks and criteria are employed. Also, measurements of performance on isolated tasks tend to yield little or no information relative to concurrent changes in complex tasks. For example, passive tasks such as those involving monitoring or vigilance have been found to be more sensitive to decrements under some conditions (e.g., duration of the work period) than tasks that engage the worker more actively (cf. Ray, Martin, and Alluisi, 1960; Alluisi, Chiles, Hall, and Hawkes, 1963). Under other conditions such as those of sleep loss, active tasks may be the more sensitive (as noted in the previous section).

Obviously, if performance is to be measured most effectively, appropriate tests should be administered under conditions as comparable as possible to the operational situation; they should measure not only performance, but also derived factors such as motivation, learning, skill, and performance reserves under realistic circumstances of work. These requirements make the study of the influence of situational factors more difficult, but difficulty should not be confused with impossibility!

Situational factors producing physiological changes. The class of situational factors discussed in the preceding sections is a behavioral one. There is another closely related class in which the situational factors produce first some set of physiological changes in the individuals concerned, and then these physiological changes are associated with behavioral changes that influence performance. The use of nonlethal chemical and biological incapacitating agents would constitute such situational factors. We shall review something of the known data with regard to the first of these, the chemical agents, but we shall not attempt to comment on the effects or possible effects of the biological agents.

Nonlethal chemical agents were first used in warfare during World War I. Subsequently, they were used in the Italo-Ethiopian War of 1935-1936. Except for a few other isolated incidents, these two conflicts have provided the only available knowledge concerning the effects of such agents when used under field combat conditions. However, laboratory studies have produced data that indicate something of their effect on individual performance.

Prior to World War II, the classes of nonlethal agents that had been used were lacrimators, sternutators, and vesicants. Interest has grown since World War II, however, in new potential classes of nonlethal chemical agents and some of these have been investigated experimentally. These new classes include (1) agents that affect the central nervous system, produce confusion, and result in the deterioration of the performance of duties, (2) agents that produce orthostatic hypotension, (3) agents that produce clouding of the cornea and associated visual disturbances, and (4) agents that produce severe pain on contact with

the oral and respiratory mucosa and with the skin, and that result in cellular necrosis. Because our interest here is in the influence of such a situational factor as the use of a chemical agent on individual performance in military systems, we shall concern ourselves with the centrally acting compounds.

A great many compounds might be termed "psychochemicals" to identify them as agents that affect the central nervous system in ways that produce psychic or behavioral effects (cf. Goodman, and Gilman, 1958). Among these compounds are the central nervous system depressants such as general anesthetics, basal anesthetics, barbiturates, aliphatic alcohols, opium alkaloids, etc. There are also central nervous system stimulants such as d-amphetamine, picrotoxin, metrazol, ritalin, and caffeine, to name a few.

In addition to these stimulants and depressants, still other psychochemical compounds have been identified. For example, the adrenal cortical hormones may produce effects on the central nervous system that are sometimes severe enough to precipitate a psychotic reaction. The psychotomimetic compounds specifically produce changes in mental functioning that are similar to those evidenced in psychotic individuals, e.g., disorders of mood, clouding of consciousness, disturbances in the time sense, difficulties in consecutive thinking, inability to communicate adequately with others, sensory illusions, disturbances of body imagery, and either or both delusions and hallucinations. Examples of such compounds include d-lysergic acid diethylamide (LSD), mescaline, and marihuana.

Since a great deal of data has been collected concerning the effect of LSD on psychological test performance, this compound may serve as a general model for indicating the type and range of effects produced by other psychotomimetic compounds, or K-agents; it must be realized, however, that other compounds of this same class may produce different reactions--reactions that are not entirely predictable. Even with the known agents it is clear that the various psychological functions affected, and the degree to which they are affected, depend on the dosage of the drug, the personality of the individual, and the situational setting in which the affected individual is placed. Much research is still needed on this topic. Nevertheless, within the limits imposed by these constraints, the following brief review of some known effects of LSD on man's performance may be taken as indicative of the wide range of effects such agents may have.

Subjective effects of LSD ingestion. Abramson et al. (1955d), by means of a questionnaire technique, attempted to discover the subjective symptoms associated with the ingestion of 50 and 100 gamma of LSD-25. Briefly, the symptoms related to the ingestion of 50 gamma (in order of decreasing significance) were unsteadiness, dream-like feelings, parasthesias, "inner trembling," pressure on the ears, difficulty in focusing vision, weakness, lightness of limbs, lips drawn back as if smiling, dizziness, and peculiar feelings of the limbs.

Symptoms associated with ingestion of 100 gamma included all those previously mentioned as occurring with 50 gamma, and, in addition, included reports of subjective sensations of things moving about the subjects and of objects seeming to be far away. Other investigators have noticed euphoria, depression, anxiety, uncontrolled laughter or crying, difficulties in communication, visual illusions, and hallucinations. Finally, high doses of more than 100 gamma sometimes produce depersonalization reactions involving loss of personal identity.

LSD and intelligence test performance. Doses of 72 to 200 gamma of LSD-25 have been found by Levine et al. (1955) and by Cohen, Fichman, and Eisner (1958) to result in decrements in performance on intelligence tests. Using the Wechsler-Bellevue Intelligence Scale, Levine found the average measured I.Q. of 21 subjects dropped from 122.9 without the drug to 111.8 with it. He noted that the primary deficits centered about difficulties in shifting set, abstract thinking, and comprehension; the subjects appeared to have difficulty in concentrating and to be easily distracted. Cohen used the Shipley-Hartford Test and found that the test score decreased when the drug was ingested in 24 out of the 30 cases he studied. Again, abstract thinking was affected more than vocabulary retention. Other investigators have not noticed decrements on standard intelligence tests, but this seeming contradiction is probably accounted for by their use of relatively low dosages or by their subjects' having developed drug tolerance.

LSD and psychomotor performances. Ingestion of 50 or 100 gamma of LSD-25 has been found to produce no decrements in a pursuit-rotor task, in speed of copying, or in tactual perception (Kornetsky, Humphries, and Evarts, 1957). No decrements in tapping speed were found after a dose of about 70 gamma in another study (Bercel, Travis, Olinger, and Dreikurs, 1956). Performances on the Dunlap Steadiness Test and on a pursuit-rotor test were not affected by a dose of 100 gamma (Abramson, Jarvik, and Hirsch, 1955a), and the same dosage left unimpaired performances on a manual reaction-time task (Abramson et al., 1955b). Thus, the data on psychomotor performances are uniquely in agreement--no disturbances seem to be created by ingestion of LSD.

Performances on tests of numerical ability. Unlike the case of psychomotor performance, performances on tests of numerical ability have shown these abilities to be affected by ingestion of LSD. Addition and subtraction have been found to be adversely affected and, in general, the higher the dosage, the lower the score obtained on an arithmetic test (Jarvik et al., 1955c). Kornetsky and his colleagues (1957) found that LSD impaired performance of digit addition; the same sort of impairment was found by Silverstein and Klee (1958), who also reported decrements occurring in the subjects' abilities to count backwards.

Performances on tests of memory. Deficits in recent memory following ingestion of between 70 and 100 gamma LSD have been reported in several studies (Bercel et al., 1956; Jarvik et al., 1955b; Silverstein and Klee, 1958). In at least one study, however, no such deficit was found following the ingestion of 50 gamma (Jarvik et al., 1955b). Also, within the range of doses used by Silverstein and Klee (1958), there appeared to be no deficits in the ability of the subjects to remember personal information. Thus it appears that the higher doses may affect adversely recent memory, but leave long-term memory unchanged; the smaller doses appear to have no affect on either type of memory.

LSD and judgments of spatial relations. The abilities of subjects to judge size, distance, parallelism, and the sizes of angles in drawings all were found to be impaired by ingestion of 70 gamma LSD (Bercel et al., 1956). Likewise, a dose of 100 gamma resulted in impairment of the ability of subjects to draw geometric figures (Silverstein and Klee, 1958) and to perform spatial-relations tasks required by the Thurstone Hand Test and the Minnesota Paper Form Board (Abramson et al., 1955c).

Attention following LSD ingestion. The ability to remain attentive and to concentrate on a task was measured by Jarvik and his associates (1955a) by means of a cancellation task. Their results indicated that performance was generally impaired following a dose of 100 gamma. Other researchers have also noted that persons under the influence of LSD-25 appear to have difficulties in concentration.

Effects of LSD on personality measures. A great deal of research making use of the Rorschach Test to measure drug-induced personality changes has been published. In general, these studies have concluded that a more childlike level of functioning and schizophrenic trends appear in persons who have ingested moderate doses of LSD. Other tests that have been used include the Bender Gestalt, the House-Tree-Person Test, the Thematic Apperception Test, and the Minnesota Multiphasic Personality Inventory. Results with all these instruments generally have been interpreted as revealing regression, anxiety, increased egocentricity, and the disruption of normal ego defenses to result from dosages of LSD.

Thus it appears that the effects of nonlethal incapacitating chemical agents such as LSD and other psychotomimetic compounds are widely variable. They are not well understood; yet, because of their behavioral effects they are highly likely to be included in an enemy's arsenal of nonlethal chemical agents. This should make it mandatory that additional research be conducted, for nonlethal chemical agents have been used during warfare in the past and it may be that they will be even more widely used in future conflicts.

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CHAPTER 8

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PSYCHOPHYSIOLOGICAL PERFORMANCE IN ACCELERATION ENVIRONMENTS

Many experiments have been conducted on the effects of acceleration environments on the psychophysiological performance capabilities of man. Some of these experiments have provided highly specific data which pertain directly to manned spacecraft systems, and others have provided more general scientific findings which contribute to the understanding of the physiological and psychological responses which man makes during exposure to acceleration stress. This paper reviews these experiments and summarizes the results of simulation studies which have provided psychophysiological performance information in support of national space projects such as X-15, Mercury, Dyna-Soar (X-20), Gemini and Apollo. An attempt is made to suggest important research problem areas and to formulate 19 general principles which describe the psychophysiological performance capabilities of man during exposure to acceleration stress.

PRIMARY STIMULUS VARIABLES

There are five primary stimulus acceleration variables, and a complex multidimensional graph would be required to show the relationships of each variable with psychophysiological performance. These variables are follows:

(a) The direction of the primary or resultant G force with respect to the X, Y, and Z axes of the human body

(b) The rate of onset of acceleration (or the rate of deceleration, whichever the case may be)

(c) The magnitude of peak G

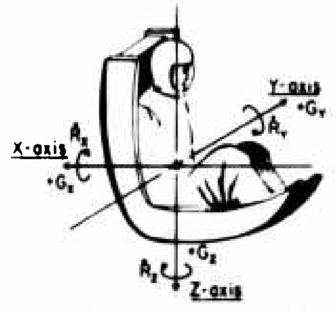
(d) The duration of peak G

(e) The total duration of acceleration from time of onset to termination

In this paper, time permits only a partial coverage of these variables. Greatest emphasis is given to the direction of the primary or resultant G force, the magnitude of peak G, and the duration of peak G.

A physiological description of acceleration is presented in Figure 1. This figure presents the nomenclature which is used in this paper, and summarizes the six degrees of freedom in which any body in space may be accelerated. Additional descriptive information is available in Clark, Hardy, and Crosbie (1961); Gell (1961); and Chambers (1963).

PHYSIOLOGICAL DESCRIPTION OF ACCELERATION



(Body Fluids, Heart Displacement, With Respect to Skeleton)

Linear Acceleration Modes

Description of Heart Motion

Actual	Other Descriptions			Symbol	Unit
Towards spine	Eye-balls-in	Chest-to-back	Backward facing	$+G_x$	g
Towards sternum	Eye-balls-out	Back-to-chest	Forward facing	$-G_x$	g
Towards feet	Eye-balls-down	Head-to-foot	Headward	$+G_z$	g
Towards head	Eye-balls-up	Foot-to-head	Footward	$-G_z$	g
Towards left	Eye-balls-left	———	Rightward	$+G_y$	g
Towards right	Eye-balls-right	———	Leftward	$-G_y$	g

$$NG = \frac{a}{g} = N_1 G_x + N_2 G_y + N_3 G_z$$

$$N^2 = N_1^2 + N_2^2 + N_3^2$$

Angular Acceleration Modes

Acceleration about X-axis (roll axis)	$\dot{R}_x$	rad/sec^2
Acceleration about Y-axis (pitch axis)	$\dot{R}_y$	rad/sec^2
Acceleration about Z-axis (yaw axis)	$\dot{R}_z$	rad/sec^2

(Angular acceleration is positive or negative by right hand rule)

Figure 1. Physiological description of acceleration

TOLERANCE TO ACCELERATION STRESS

Tolerance to acceleration stress is generally considered to be of two basic types, physiological tolerance and performance tolerance. Physiological tolerance to acceleration is defined as the physiological ability to sustain, endure, or withstand the stress. Many different criteria are used to measure physiological tolerance. These include primarily cardiovascular, respiratory, visual, and pain criteria. Performance tolerance, as originally defined by Chambers and Nelson (1961),

refers to the end points for reliable functioning of any particular overt behavior system during exposure to the acceleration stress. The specifications and development of performance tolerance curves are dependent upon the identification and quantification of performance errors so that the amount of impairment of performance proficiency may be measured as a function of acceleration stress. Under conditions of high gravity, performance proficiency deteriorates markedly. The amount of measured deterioration varies, however, depending on whether the criteria involve primarily motor skills, continuous tracking skills, reaction time, higher mental abilities, memory and recognition, or perceptual abilities. High acceleration stress affects these abilities at different rates and in different amounts.

The criteria for physiological tolerance to positive acceleration ($+G_z$) are usually indicated in terms of grayout, blackout, or unconsciousness. The condition when the subject is unable to perceive objects in his peripheral field of vision is called grayout. If he fails to respond to an illuminated central light, the condition is called blackout and the next stage in severity is unconsciousness. Sometimes unconsciousness is followed by a convulsion, if the acceleration is not terminated promptly. The test procedure for making these determinations is summarized in Figure 2. Other criteria of physiological tolerance to positive acceleration include the electrocardiographic recordings, as monitored by the attending flight surgeon, and the subject's own subjective reports of pain or discomfort. For the other types of acceleration the criteria are not so quantitative. For positive transverse acceleration ($+G_x$), the primary symptoms include severe chest pain, extreme difficulty in breathing, discomfort in the extremities, extreme fatigue, visual dimming or loss of peripheral vision, and blurring and tearing of the eyes. For negative transverse acceleration ($-G_x$) the signs and symptoms include severe pain in the eyes and extremities, visual blurring, tearing, extreme difficulty in focusing, periorbital pain, and retinal hemorrhage. Effects of negative acceleration ($-G_z$) include severe visual blurring, excessive pain in the eyes and head, excessive tears, redout, and retinal hemorrhage. During high G spin and tumbling maneuvers, when the subject is exposed to an angular acceleration around any particular body axis, any or all of these effects may be shown, depending on the specific acceleration environment.

The criteria for physiological tolerance to acceleration are highly dependent upon: (a) quantitative information available at the time of the acceleration test, (b) the subjective judgment of the attending flight surgeon who is monitoring the test runs, and (c) the subjective feelings of the test subject himself. Factors such as fear and anxiety, confidence in one's self and in the testing apparatus, and willingness to tolerate discomfort and pain are important subjective factors. Competitive attitude, desire to be selected for a particular space project, recognition, and incentive pay are important motivational factors. Other important factors include the amount of previous acceleration training, the subject's breathing and straining techniques, the age of the subject,

environmental test factors such as temperature and ambient pressure, and the type of acceleration protection device in which the subject is being tested.

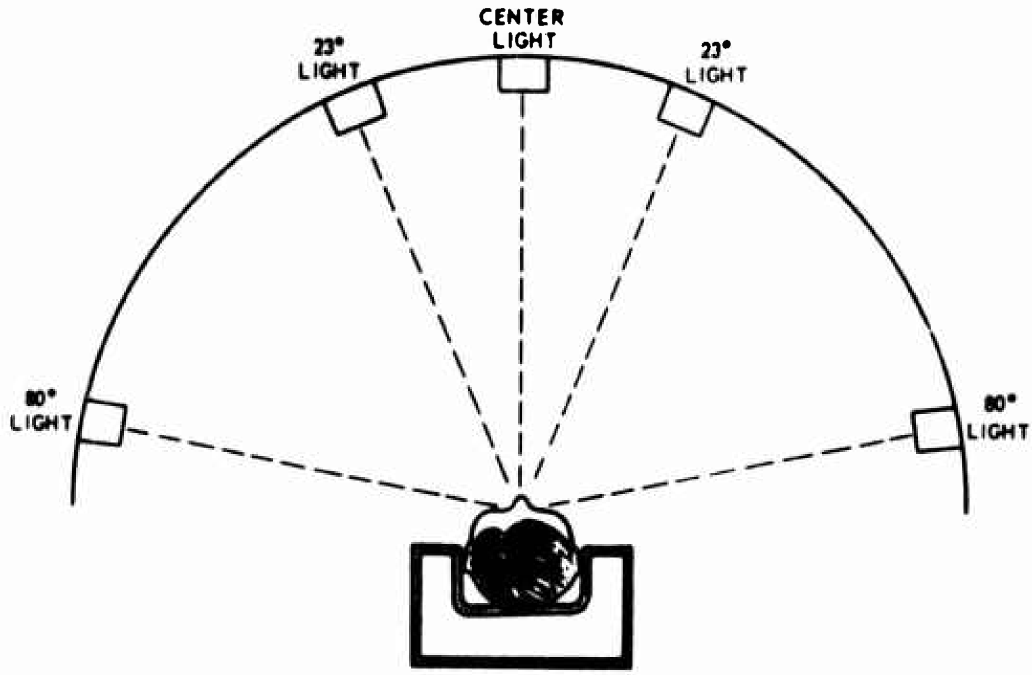


Figure 2. Procedure for measuring the positive acceleration value at which grayout occurs. (The subject attends the center light, and responds to the random presentations of the peripheral lights (usually placed at 23°) by operating a small switch with his hand to turn off each light as rapidly as he can as it is continuously turned on by the illumination stimulus programmer. As G increases, ability to detect the peripheral lights decreases until the subject fails to respond. This is called grayout, and is expressed in terms of the G level at which he first consistently fails to respond. If G continues to increase, a point is soon reached at which the subject loses all vision. This is called blackout, and is expressed in terms of the G level at which vision is completely lost. At different centrifuge facilities, there have been many variations in the position of the peripheral lights. This figure illustrates the two extreme positions (23° to 80°) which have been most frequently studied.)

There have been many experiments conducted on the physiological tolerance of the human body to acceleration. Some physiological tolerance curves are presented in Figure 3, which shows the results of approximately 20 experiments that have been summarized for the purposes of this presentation. The figure shows some of the more important relationships between magnitude and duration of acceleration for positive acceleration ($+G_z$), transverse supine acceleration ($+G_x$), negative acceleration ($-G_z$) and transverse prone acceleration ($-G_x$). It also shows that the average acceleration load which a subject can sustain for any given duration is higher for $+G_x$ than for the other acceleration vectors. The primary limiting factors for $+G_x$ are respiration difficulties and fatigue; for $-G_x$, the primary limiting factors are visual decrement and periorbital pain; for $+G_z$, visual grayout and blackout, and for $-G_z$, excessive pain in the head and eyes.

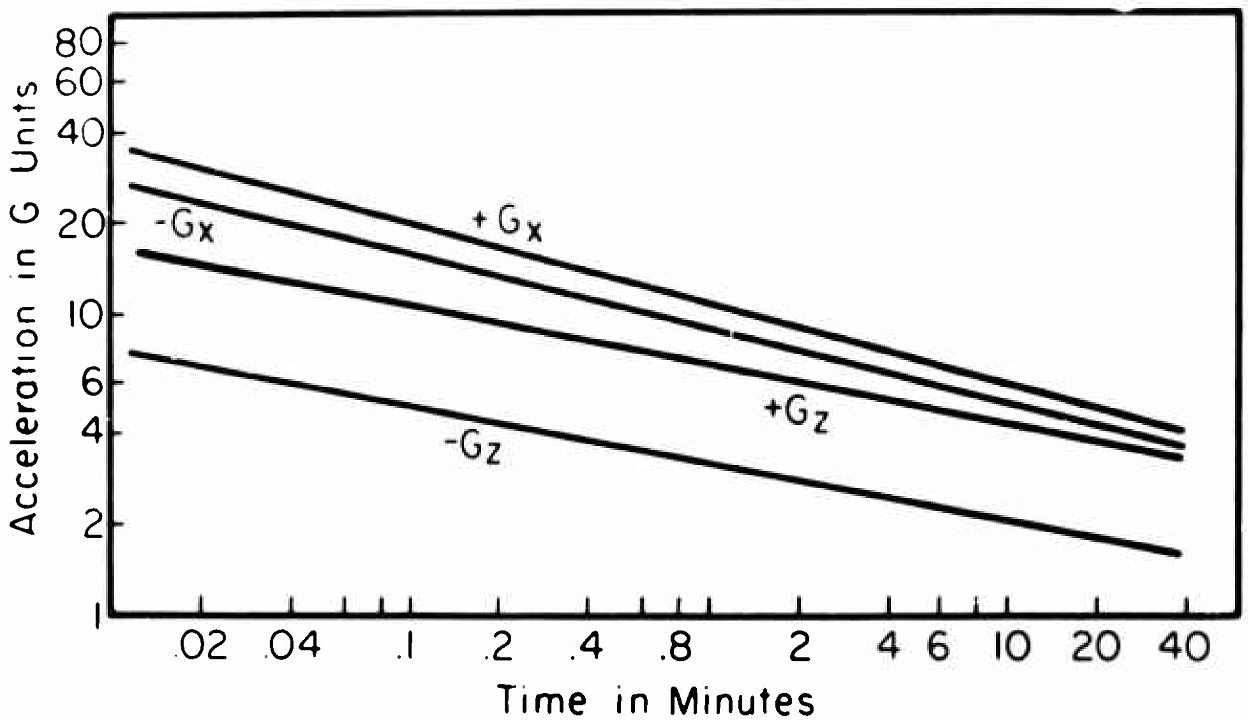


Figure 3. Average acceleration tolerances for transverse supine acceleration ($+G_x$), transverse prone acceleration ($-G_x$), positive acceleration ($+G_z$) and negative acceleration ($-G_z$).

Performance tolerance curves are not as readily constructed. There has not been a sufficient number of experiments to provide data for a summary type of figure showing performance tolerance limits. However, several experiments have been conducted to obtain performance tolerance data. Figure 4, for example, summarizes the results of an experiment conducted on the Aviation Medical Acceleration Laboratory (AMAL) Human

Centrifuge in which a group of healthy well retrained pilots attempted to sustain relatively high $+G_x$, $-G_x$, and $+G_z$ acceleration vectors for as long as they could, while maintaining satisfactory performance on a piloting tracking task. The criteria for these runs were (a) medical, e.g., termination only at the occurrence of cardiac or respiratory problems as judged by the attending flight surgeon, and (b) performance, e.g., maintaining at least 50% performance proficiency, as judged by a performance monitor who was observing on-line recordings of each pilot's tracking performance. This figure presents some outstanding time-tolerance data for each of these three different acceleration vectors. Performance tolerance data can only be obtained when performance quantities are recorded on-line as the runs proceed, and relatively few experiments have actually reported this kind of information. Physiological tolerance limits tend to define certain performance tolerance boundaries. Skill decrement usually occurs prior to physiological decrement; however, this is not always the case (Chambers, 1963). Much research is needed to determine the relationship between physiological tolerance limits and performance tolerance limits.

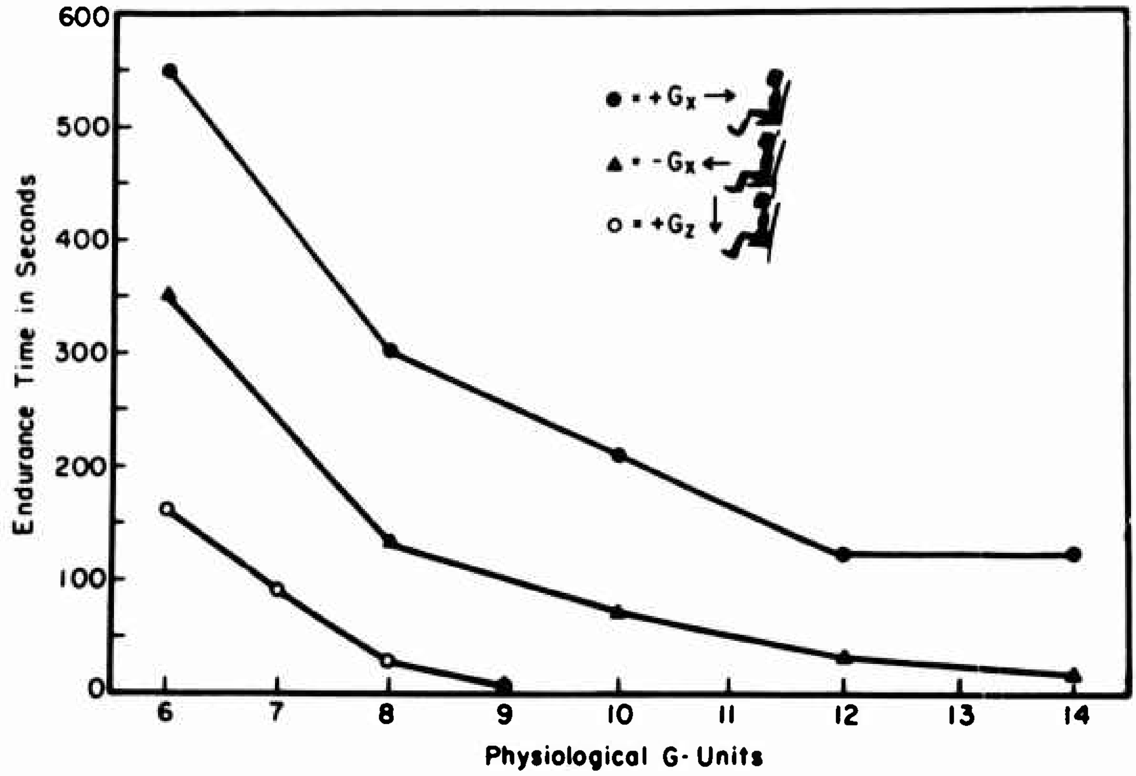


Figure 4. Endurance time in seconds vs. physiological G units for a group of highly motivated pilots

In the above figure, the performance tolerance criterion was that the pilot must maintain at least 50% of his maximum piloting performance proficiency. This is an arbitrary amount, and for any given experiment it is necessary to establish the acceptable criteria. In Figure 5, for example, the estimated performance decrement for 5 seconds at +15 G_x was 78%. Decrement was less for lower acceleration loads. The degree of performance decrement which can be considered as being the performance tolerance limit is somewhat arbitrary in most cases. Consequently, the development of performance tolerance curves which have general application will be delayed until acceptable standards can be reached and agreed upon by acceleration researchers (Chambers and Hitchcock, 1963).

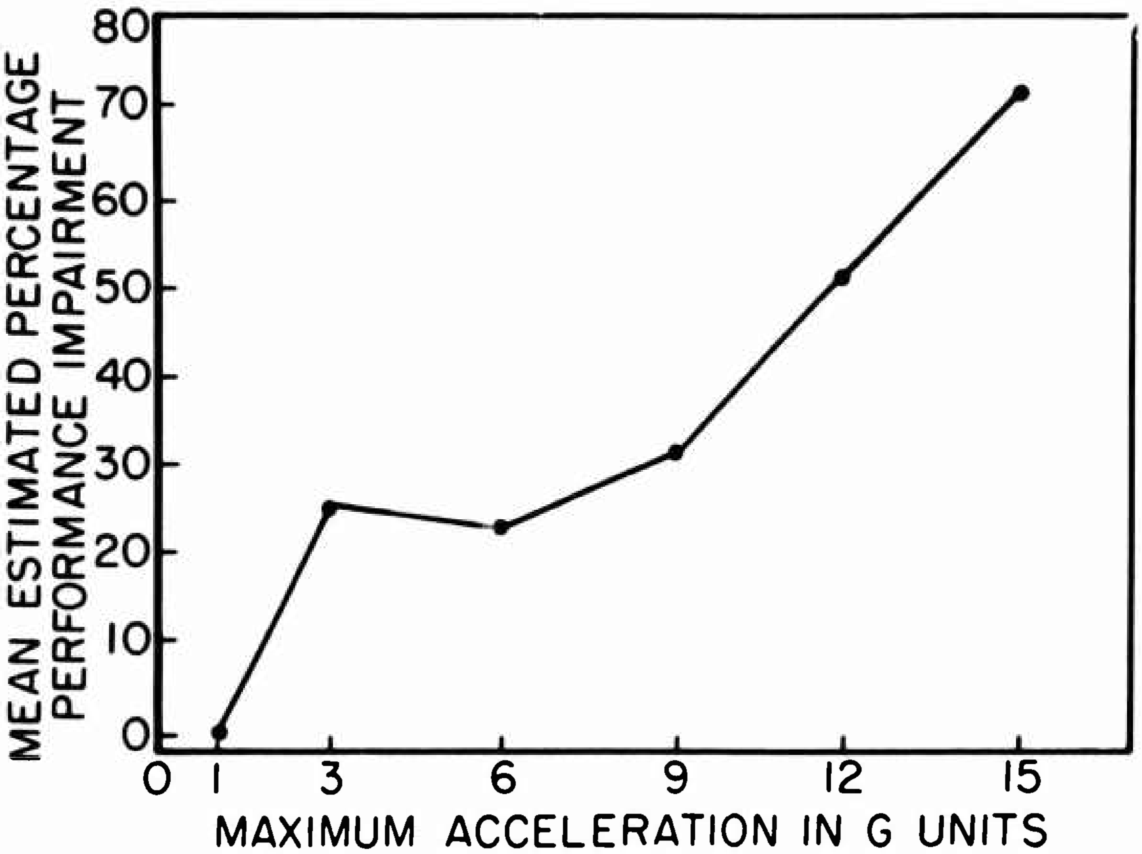


Figure 5. Average estimated performance decrements by pilots who performed complex launch and insertion maneuvers through peak accelerations of 1, 3, 6, 9, 12, and 15 G_x. (Chambers and Hitchcock, 1963)

This problem is made more difficult by the fact that physiological responses, such as EKG, respiration, and blood pressure, are not necessarily related to pilot performance during acceleration stress in any definable or predictable way. An example of this is shown in Figure 6, in which a comparison is made of physiological and performance measures taken on a subject during high G. In this example, performance impairment appeared suddenly and was complete, while the physiological decrement was not noticeable from the recordings. Here, EKG, pulse, respiration, blood pressure, tracking efficiency, pitch error, heading error, roll control , pitch control and yaw control were measured. In this particular example, tracking efficiency was calculated in percentage units based on accumulated tracking error divided by the accumulated excursion of the target display which the pilot was monitoring. Pitch and roll control inputs were made with a small pencil controller, and proficiency could range on a percentage scale from 100% to -100%, as derived from the division of the actual control output by the required output. This figure clearly shows that the tracking efficiency dropped suddenly and markedly from nearly 90% to approximately -95% near the end of the run. However, very little physiological change is shown except for a slight change in respiration.

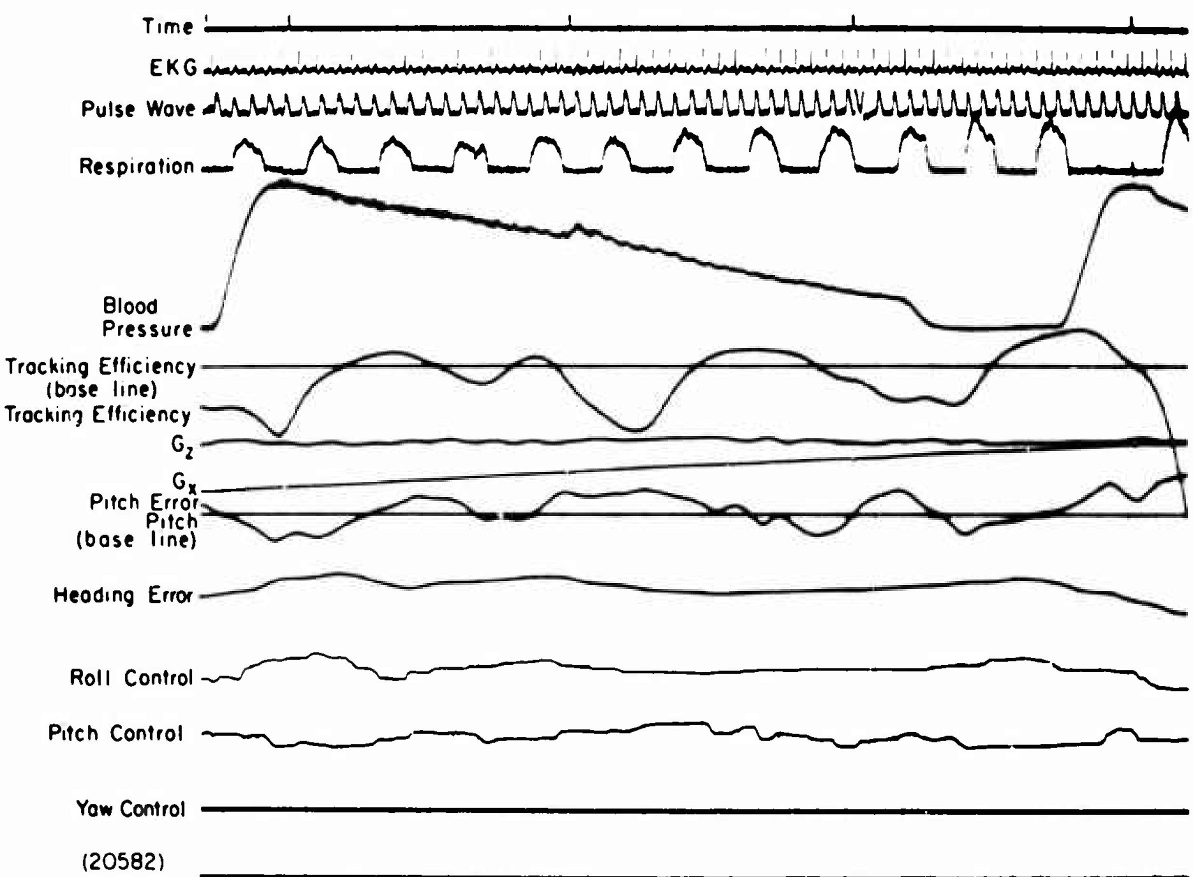


Figure 6. Comparison of physiological and performance measures recorded under acceleration stress

EFFECTS OF ACCELERATION ON PHYSIOLOGICAL FUNCTIONS

A description of the physiological events which are associated with acceleration stress is necessary at this time. For the purpose of this paper, the discussion is limited to two types of acceleration vectors: positive acceleration ($+G_z$), and transverse acceleration ($+G_x$). The physiological effects of acceleration are largely dependent upon the direction of the primary acceleration vector with respect to the human body. In the $+G_z$ vector, the obvious physiological effects are primarily retinal and cerebral, and these effects are due largely to cardiovascular inadequacy. During positive acceleration exposures which are of sufficient magnitude to produce loss of vision, there is an immediate decrease in blood pressure at the head level, a decrease in the amount of blood in the head, an increase in the heart rate, a decrease in amplitude of the arterial pulse at the level of the ear, a failure of peripheral vision, and eventually a loss of central vision. In addition to the above effects, pooling of venous blood occurs in the lower extremities, and in the splanchnic region. There is a decrease in venous return to the heart, and an associated lowering of cardiac output.

Of most interest, perhaps, are the hydrostatic effects of positive acceleration on vision, and the effects which manifest themselves at levels below those affecting unconsciousness. The intraocular pressure is approximately 20 mm Hg higher than the intracerebral pressure. Consequently, blood supply to the retina fails before failure of the cerebral circulation. Lambert (1945), using a specially designed pair of suction goggles applied to the eyeballs, found that the application of 30 to 40 mm Hg negative pressure to the eyeball raises the blackout threshold. Duane (1954) and others have illustrated that there is a correlation between visual change and change in the fundus oculi. Associated with the subjective loss of peripheral vision is the arteriolar pulsation, i.e., recurrent exsanguination. Associated with the subjective experience of blackout is arteriolar exsanguination and collapse. Associated with the return of central and peripheral vision is the return of arteriolar pulsation and temporary venous distension. In later work, Duane, et al (1962) observed that where the hydrostatic pressure was such as to cause collapse of the arteriolar vessels during diastole and recovery, in systole a pulsation of the vessels may be observed which is associated with grayout, or reduction of the visual field to approximately 15 degrees in all meridians. In addition, in those subjects in whom a photic drive of the EEG was observable at rest, loss of photic drive could be demonstrated at grayout levels. The inner retinal layers are sensitive to hypoxia. It is theorized that the retinal arteriolar ischemia produced hypoxia of these layers. The critical site of hypoxia is believed to be the junction of the ganglion and bipolar cells in the retina.

While the major part of the cerebral hypoxia that ensues under positive acceleration is no doubt due to inadequacy of the blood flow, there is some evidence that prolonged positive acceleration could

produce marked arterial hypoxemia. Arterial desaturation develops during prolonged exposures to positive ($+G_z$) acceleration, despite an accompanying increase in respiratory minute volume. For example, Barr (1963) found that arterial saturation during a 2-minute exposure to +5 G_z dropped from a mean of 96.2% to 87.4% while the alveolar oxygen tension fell to a mean of 58.0 mm Hg.

Respiration rate and tidal volume increase and vital capacity decreases during exposure to positive acceleration. The decrease in vital capacity is due in part to a limitation in inhalation imposed by downward pressure on the thorax. Overall pulmonary efficiency is lowered. In a study by Barr (1963), it was found that human subjects exposed to +5 G_z for 1 minute (wearing G suits), had an initial apnea for a few seconds with onset of acceleration, followed by a marked increase in respiratory rate and volume, persisting throughout the acceleration and for some time after the acceleration ceased. During exposures of +5 G_z for two minutes, expired minute volume increased from 8.6 to 20.8 liters per minute, and effective alveolar ventilation increased from 4.9 to 9.6 liters per minute. Arterial to end-tidal CO_2 difference increased by 8.0 mm Hg and was responsible for the major part of the accompanying decrement in end-tidal CO_2 tension. Oxygen uptake increased from a pre-run value of 269 to 410 ml per minute, whereas CO_2 elimination increased from 216 to 391 ml per minute, resulting in a change in the respiratory exchange ratio from 0.80 to 0.96.

Electrocardiography has been a major tool of research in the physiology of positive acceleration. Pulse rate progressively increases with acceleration. Brown and Fitzsimons (1957) report that the rise in pulse rate is produced by stimulation of the carotid sinus brought about by the fall in blood pressure, and also by an adrenal medullary response, brought about by apprehension. This latter aspect is supported by the fact that in most subjects, an increase in pulse rate is observed before the actual onset of acceleration, while the maximum drop in blood pressure is reached several seconds after onset.

Major EKG changes occur in the electrical axis. These appear to be among the primary changes. In addition, there are some S-T segment and some non-specific T-wave changes. They are indicative of cardiac strain and are most likely to occur 10 to 20 seconds before visual disturbance. The P-R interval shortens concomitantly with the pulse rate. Under high positive G stress and high pulse rate (190/min), the P-wave may not be distinguishable from the S-T complex. Sometimes there are bursts of cardiax arrhythmia, bradycardia, marked sinus arrhythmia, extrasystoles, and displacement of the pacemaker. If these conditions persist, or if G increases, unconsciousness from cerebral hypoxia results. Actually, there are two types of unconsciousness which can result. One is associated with hypertension at the heart level, but inadequate tension at the eye level. The other is associated with failure of compensation, hypotension at heart level, and syncope. Convulsions may follow. Frank et al (1945) found that convulsions and EEG

changes occurred in 52% of 230 subjects and in 40% of 591 tests producing unconsciousness. These were usually slight colonic seizures involving all or some of the extremities, face, and trunk.

During exposure to transverse acceleration ($+G_x$) the increase in hydrostatic pressure is much less than for positive acceleration because of the shorter distances involved. During transverse acceleration, the limitations are largely respiratory in nature, although during extremely high acceleration some hydrostatic effects are great enough in the eye and brain to be significant, and petechial hemorrhage occurs on dependent surfaces of the body.

The respiratory rate increases almost linearly with acceleration. Recent data illustrating this increase in respiration rate up to $+12\ G_x$, and the associated decrease in tidal volume are shown in Figure 7. As shown in this figure, minute volume also increases, but it levels off at $+8\ G_x$. Tidal volume, expiratory reserve volume and total lung capacity decrease as G increases. There is a marked increase in oxygen consumption as transverse acceleration increases. Data on this up to $+12\ G_x$ are shown in Figure 8. These factors all point to a significant interference in pulmonary ventilation, and the fact that the severity of this interference increases as $+G_x$ increases. As far as the pilot is concerned, he is required to work much harder to satisfy his breathing requirements. Figure 9 presents an example of data collected from a subject while riding a $10\ G_x$ profile on the AMAL Human Centrifuge. The respiration rate and heart rate were recorded on magnetic tape and later analyzed, as shown in this figure, to illustrate the increase and decrease in heart rate and respiration as a function of $+G_x$.

It is believed that there is an increase in O_2 uptake under transverse acceleration. However, some investigators believe that there is a reduction in O_2 consumption and an increase in CO_2 retention during transverse acceleration. It may be that the reduction in O_2 consumption may represent diminution of the arterial oxygen content, due to pulmonary shunting and diminishing peripheral utilization, which results in part from inadequate perfusion of portions of the usually perfused peripheral vascular bed. There appears to be a decrease in diffusion capacity, the significance of which is not clear. Much of it may be due to the development of pulmonary edema, and a decrease in functional alveolar area in contact with functional capillaries.

Arterial oxygen desaturation occurs under transverse acceleration and diffusion capacity also is reduced. At the Aviation Medical Acceleration Laboratory (Alexander et al, 1964) it was demonstrated that following an initial rise, probably due to hyperventilation, there is a rapid and almost linear fall to a minimum of about 81% at $10\ G_x$ (See Fig. 10). This minimum can be maintained for a short time. On cessation of acceleration, there is a rapid climb to about 93% during the first 30 seconds, followed by a prolonged recovery over the next

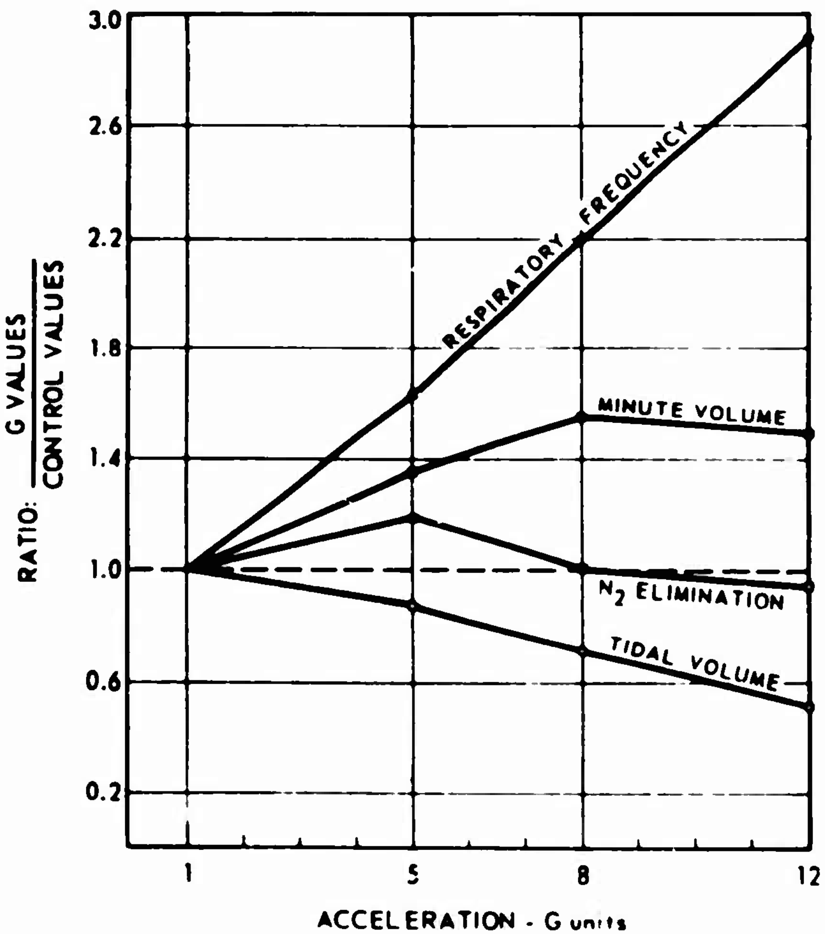


Figure 7. Effects of G_x on respiratory frequency, tidal volume, minute volume, and nitrogen elimination. (From Zechman et al, 1960).

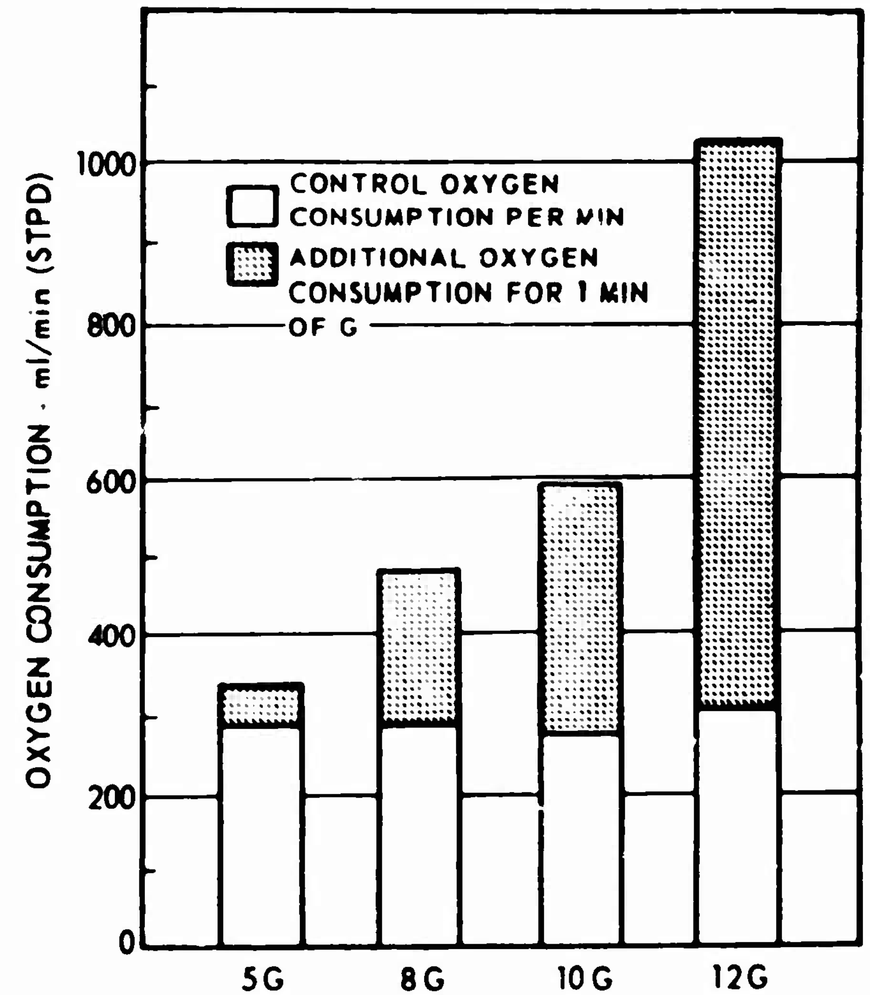


Figure 8. Oxygen consumption during transverse accelerations at 5, 8, 10, and 12 G_x

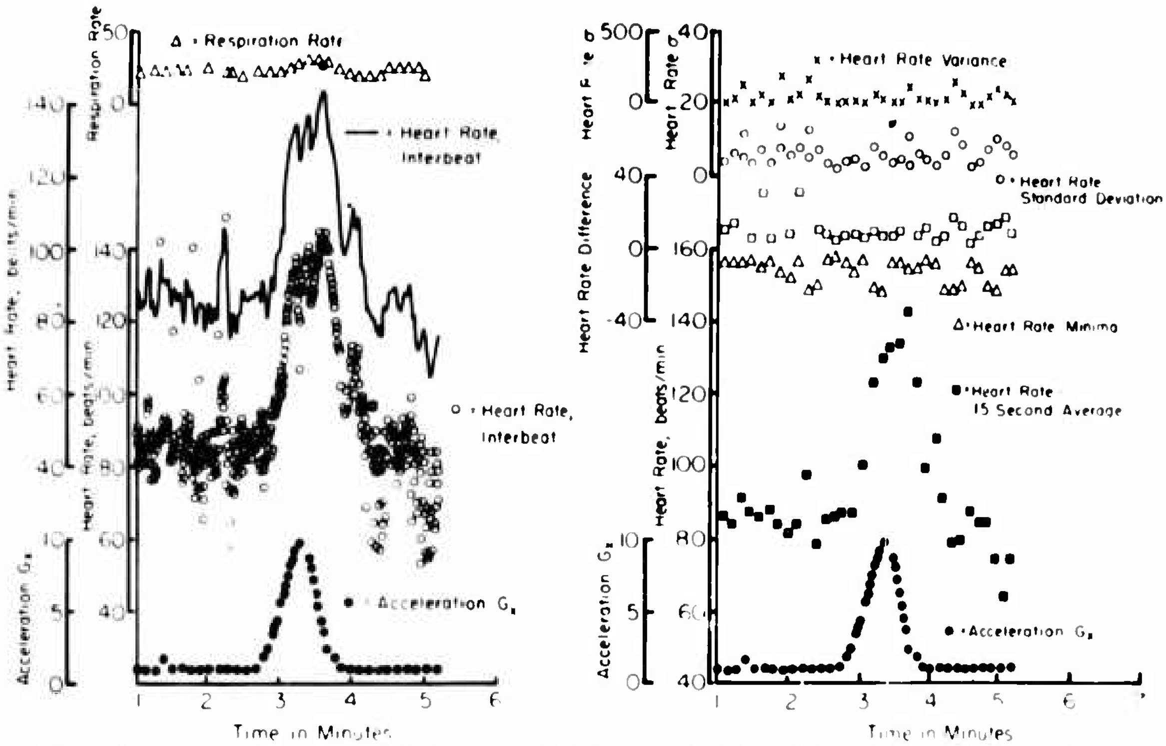


Figure 9. Example of data collected from the AMAL Human Centrifuge. (Subject was exposed to a transverse acceleration profile as heart rate and respiration rate were recorded on magnetic tape and later analyzed.)

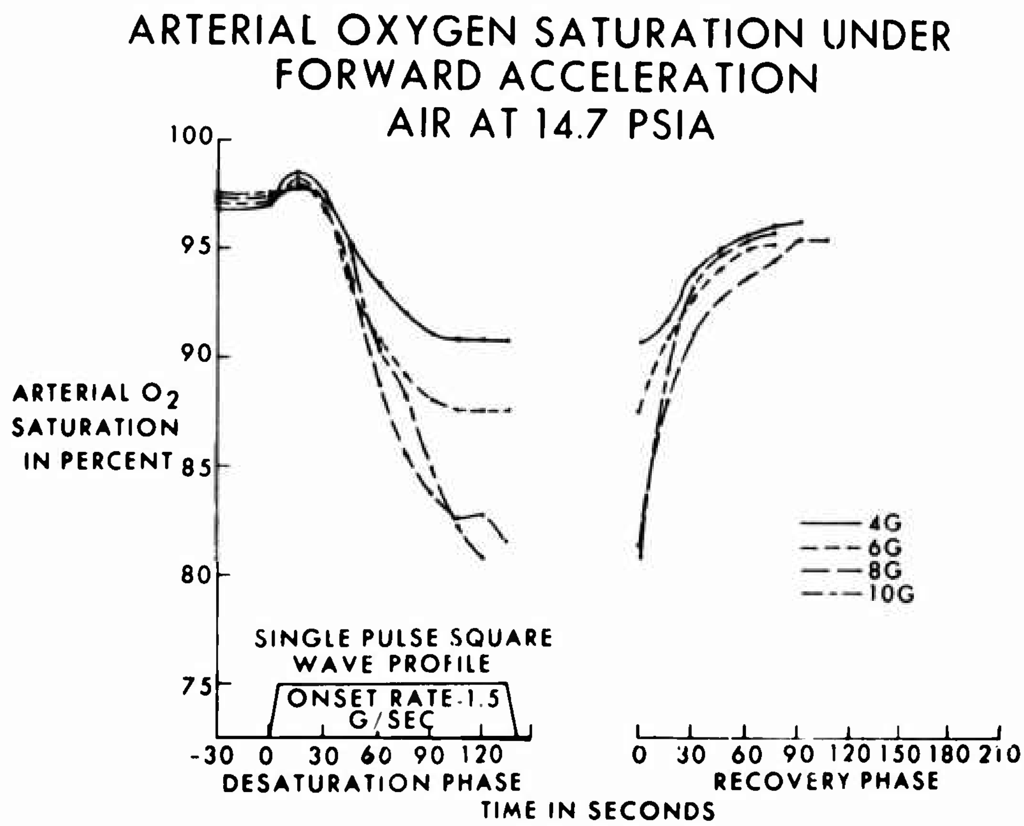


Figure 10. Effects of 4, 6, 8, and 10 G_x on the oxygen saturation of the arterial blood of 25 pilots in a supine position on the AMAL Human Centrifuge. (An ear oximeter was used to measure oxygen saturation throughout each of the profiles.)

several minutes. Even at 6 G saturation falls to a little over 85% (See Fig. 11). Using 100% oxygen at 5 psi, saturation was less, and the rate of desaturation is slower. In another study using the AMAL Human Centrifuge, Reed et al (1964) measured arterial oxygen saturation at 7, 8, 9, and 10 G_x. They found, using air breathing, that a drop of about 3% in saturation developed in about 10 seconds. After approximately 80 seconds, the saturation was near the 60 to 70% level.

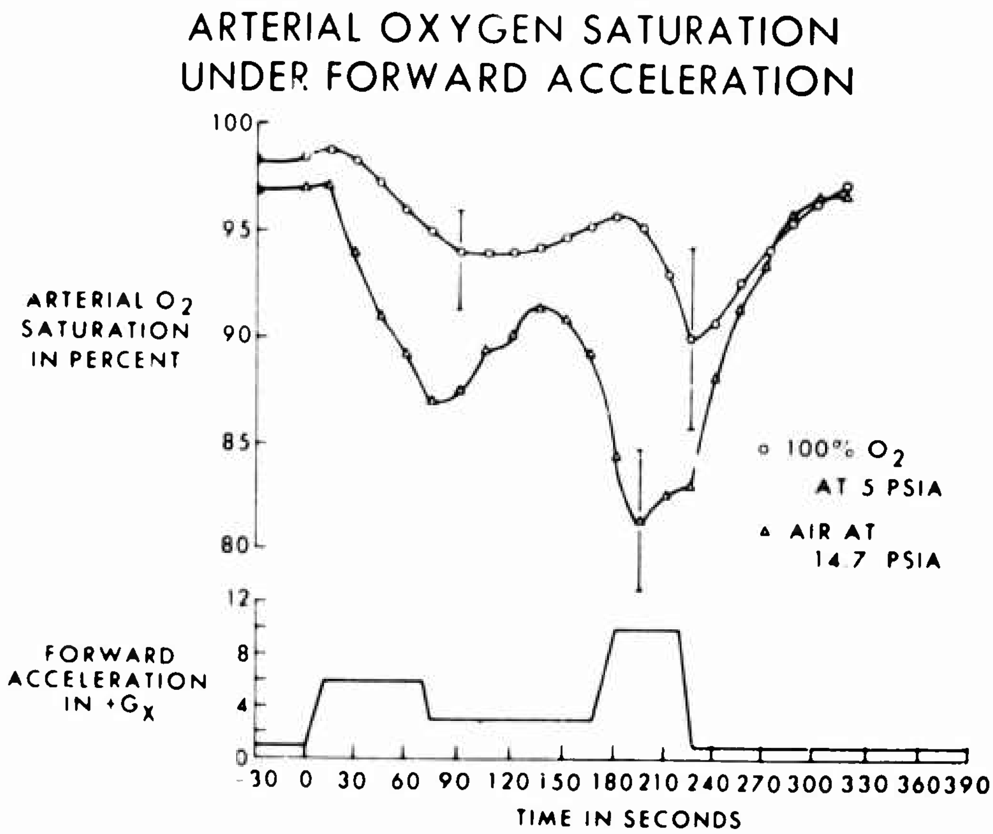


Figure 11. Effects of transverse acceleration on arterial oxygen saturation level

Up to 5 G_X there is little cardiac output change in man. Stroke volume appears to hold constant, at least to 5 G_X. Pulse rate has been found to vary some, however, and this is essential in the maintenance of cardiac output. In the G_X position, the relative change in heart rate appears to depend upon the position of the carotid baroreceptors in relation to the position of the trunk. Presumably this is due to alteration produced by acceleration on the perfusion pressures in the carotid arteries. Lindberg (1962) observed increases in mean aortic pressure, and in right arterial pressure. At higher levels of positive transverse acceleration ($+G_X$), there may be some minor changes in P-wave, deviation

of the electrical axis to the right, low voltage R and T in the chest leads, and an enlargement of S and Q. These may be interpreted as indicating an increased pulmonary artery pressure with high ventricular and auricular preponderance, resulting from compression of thoracic contents and a shift in the anatomical position of the heart.

EFFECTS OF ACCELERATION ON VISUAL PERFORMANCE

Visual disturbances occur during exposure to acceleration stress. The physiological mechanisms of vision loss during high acceleration have already been presented. This section emphasizes the visual performance of the eye under conditions of positive and transverse acceleration stress.

During positive acceleration, visual disturbances result primarily from ischemia, although some mechanical distortion of the eye also may occur. Generally, a period of grayout occurs before blackout. Grayout is characterized by general dimming and loss of peripheral vision. Blackout, which is characterized by total visual loss, occurs approximately one G unit above grayout. There have been many research experiments on the relation of positive acceleration on grayout, blackout, and unconsciousness. The major relationships among amplitude, duration, rate of onset of positive acceleration, time to grayout, and time to blackout, are complex. Figure 12, which is based on 1000 subjects tested under centrifuge laboratory conditions, summarizes these relationships.

Since grayout and blackout are not usual test criteria for transverse acceleration as they are for positive acceleration, visual performance curves for transverse acceleration have not been completely obtained. However, in a recent experiment on the AMAL Human Centrifuge, data were collected on a group of volunteer subjects who were exposed to +14 G_X in a series of runs in which back angle was varied. Points at which peripheral vision blur occurred (as reported by the subjects) and at which grayout and/or blackout occurred (as reported by the subjects, or as observed in the closed-circuit television screen by the medical monitor) are presented in Figure 13. Since during exposure to transverse acceleration it is extremely difficult to separate grayout and blackout quantitatively, the upper line in this figure includes both phenomena.

When the acceleration is transverse, there is much less visual decrement. At levels between 6 and 12 $+G_X$, there may be some tearing, apparent loss of peripheral vision, and some difficulty in focusing the eyes. For $-G_X$ at these levels, vision may be temporarily impaired, some pain may be experienced, and small petechiae may occur on the lower surface of the eyelids. However, no internal damage has been reported for accelerations as high as -15 G_X. The problem of seeing under transverse accelerations appears to be largely a mechanical problem, due partially to mechanical pressures on the eyes and the accumulation of tears.

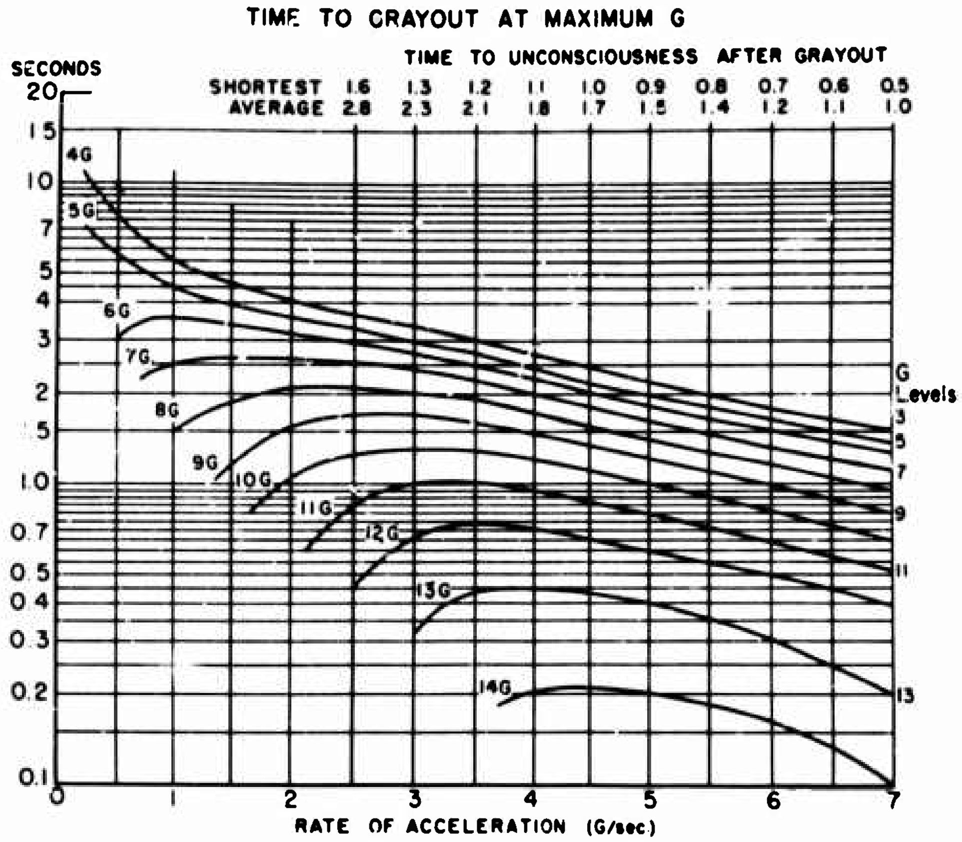


Figure 12. Relationships among amplitude, duration, and rate of onset of positive acceleration for grayout (Stoll, 1956)

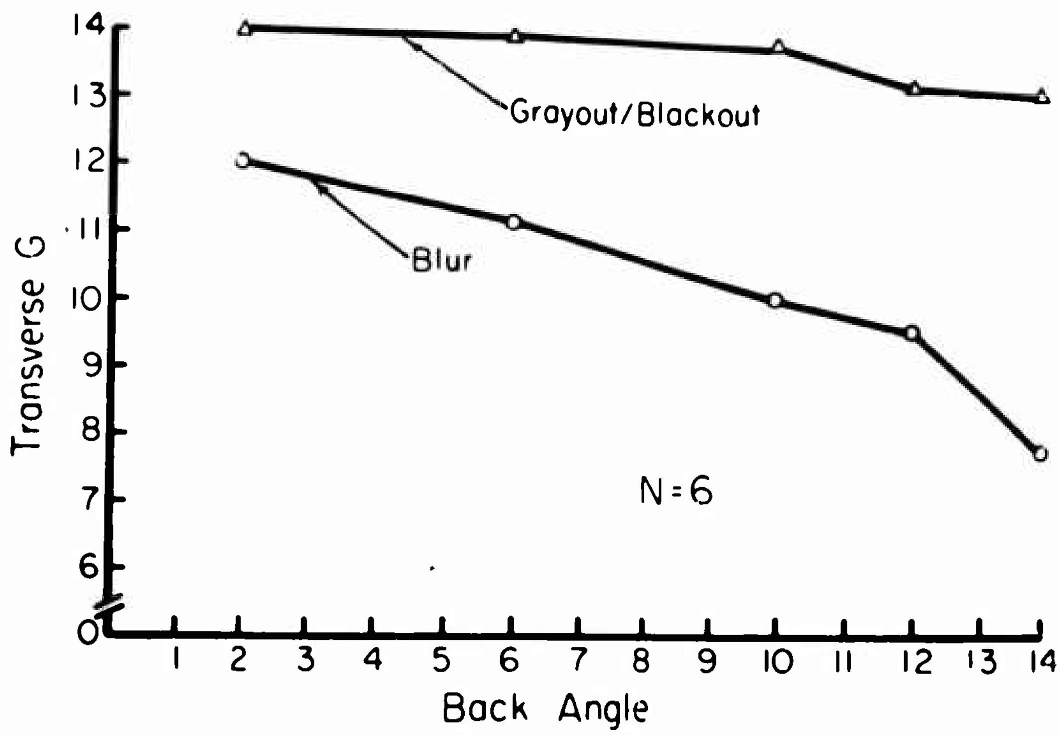


Figure 13. Grayout/blackout, and blur, as a function of back angle during exposure to transverse acceleration. (For this group of subjects, the rate of onset was 1.5 G/sec.)

However, in addition to amplitude and direction of acceleration, duration is of major importance. Endurance time to transverse acceleration is largely dependent upon the type of G-protection which is provided for the pilot.

Using the AMAL centrifuge, it has been possible to achieve endurance record runs for transverse acceleration of 127 seconds at 14 G_x, and 71 seconds at -10 G_x. Satisfactory vision was maintained during these runs. The pilots were able to see a complex tracking display well enough to perform satisfactorily throughout these runs.

Transverse acceleration influences the pilot's ability to read instruments in his cockpit. As the magnitude of G increases, visual acuity decreases. However, a given level of visual acuity may be maintained by increasing the size of the target or by increasing the amount of luminance. At high luminance, the impairment due to G is not as great as it is for the same G at lower levels of luminance. In most acceleration situations it is important to know the amount of contrast required by the pilot in order to see at any particular acceleration level, because as acceleration increases, the amount of contrast required increases.

A recent study conducted on the AMAL human centrifuge demonstrated that the minimally acceptable (threshold) contrast was greater for positive acceleration than for transverse acceleration (Chambers et al, 1962). Each subject in the centrifuge viewed a circular test patch, and during each run made approximately 15 responses, each of which was at peak G for 90 seconds. Using six healthy subjects with 20/20 vision, brightness discrimination thresholds were determined at transverse acceleration levels of 1, 2, 3, 5, and 7 G_x, for background luminances of .03, .29, 2.9, and 31.2 foot-lamberts. Figure 14 shows the obtained relationships between brightness discrimination threshold and background luminance for each of the five levels of transverse acceleration. This figure shows that for each of the five transverse acceleration conditions the visual contrast requirements increased as the background luminance decreased. For any given background luminance level, the higher acceleration levels required more brightness contrast. Figure 15 shows similar data for G_z accelerations.

ORIENTATION AND VESTIBULAR FUNCTION

For providing the sensations and perceptions necessary for maintaining continuous position orientation and motion orientation, the human pilot has three primary systems of sensory input: (a) the visual system, (b) the labyrinthine system (vestibular apparatus of the inner ear), and (c) the extralabyrinthine system (peripheral pressure, muscle, and posture senses). All three systems respond to stimuli associated with linear and angular acceleration. The vestibular (or labyrinthine) system has two distinct orientation functions: (a) one concerned with sensing the <u>position</u> of the head, and (b) one concerned with sensing

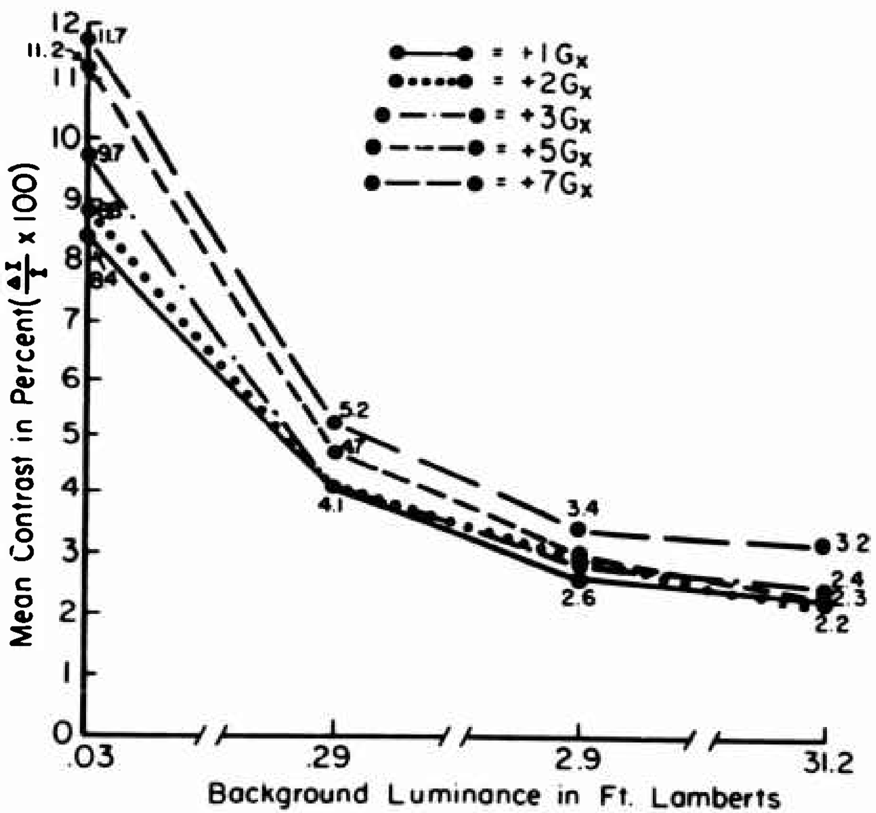


Figure 14. Relationships between brightness discrimination threshold and background luminance for each of five levels of transverse acceleration (As measured on the AMAL Human Centrifuge)

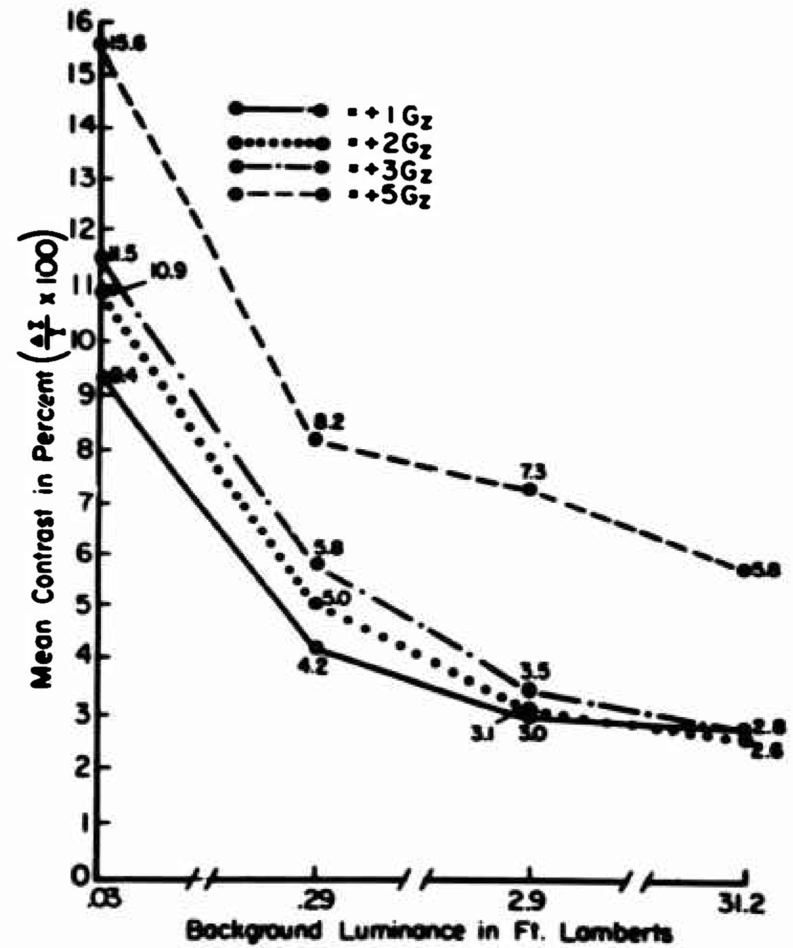


Figure 15. Results of experiment showing relationship between brightness discrimination threshold and background luminance for four levels of postive acceleration

changes in the rate of motion. The former is mediated primarily by the otolith organs, and the latter primarily by the crista ampullares and associated cupula of the semicircular canals.

For sensitivity to linear acceleration, it is theorized that the otoliths respond to the differential pull of gravity upon them. The otoliths within the utricle are primarily responsible for the static position sense. The effective stimulus is the pull of gravity, the sensory cells being differentially stimulated in different positions.

Man is very sensitive to these positions. In Figure 16, for example, ability to perceive angular acceleration, shown in terms of the time which is required for a subject to make judgments of the direction of rotation about the yaw axis, is plotted as a function of the angular acceleration. It is noted that the subjects in these experiments could make judgments for angular accelerations as small as 0.02 degrees/sec^2. Similarly, Figure 17 shows percentage of correct responses for rates of angular acceleration. At about 0.15 degrees/sec^2 there were approximately 65% correct responses. At rotation rates of approximately 0.6 degrees/sec^2, there were approximately 99% correct responses.

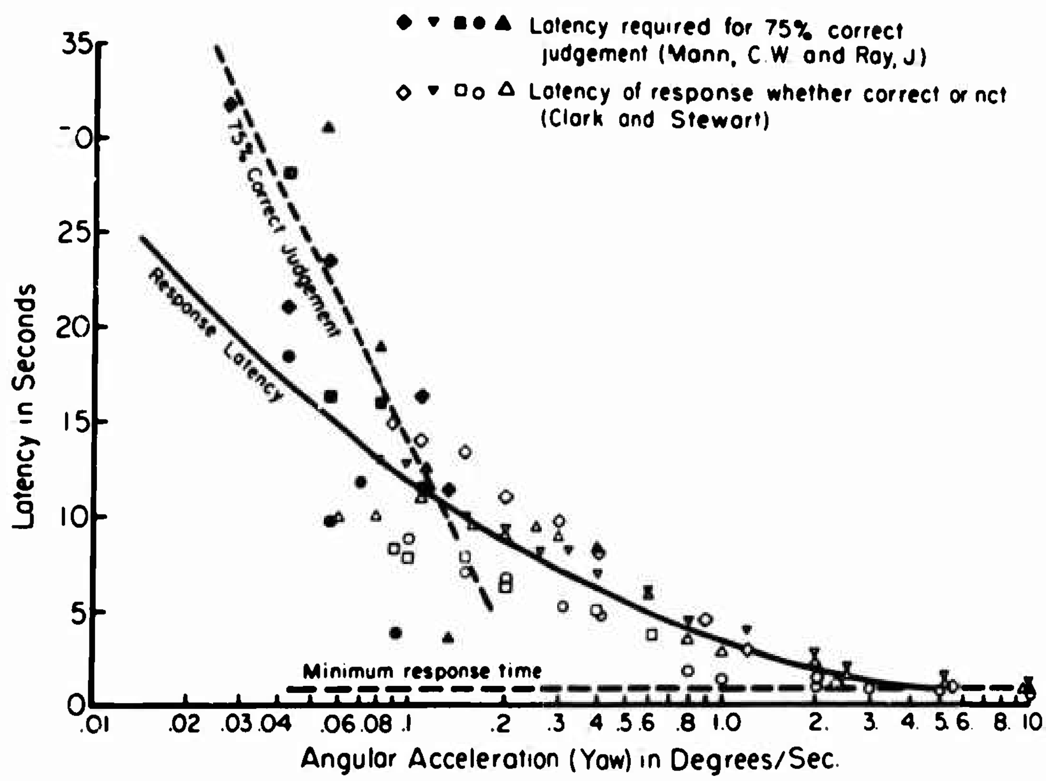


Figure 16. Perception of angular acceleration, indicated as the time required to make judgments of the direction of rotation about the yaw axis plotted as a function of angular acceleration. [The solid points indicate the time required to make judgments which are correct 75% of the time as determined by Man and Ray (1956). The open points represent the time required to make judgments, whether the judgments are correct or not, and are redrawn from the data of Clark and Stewart (1962)]

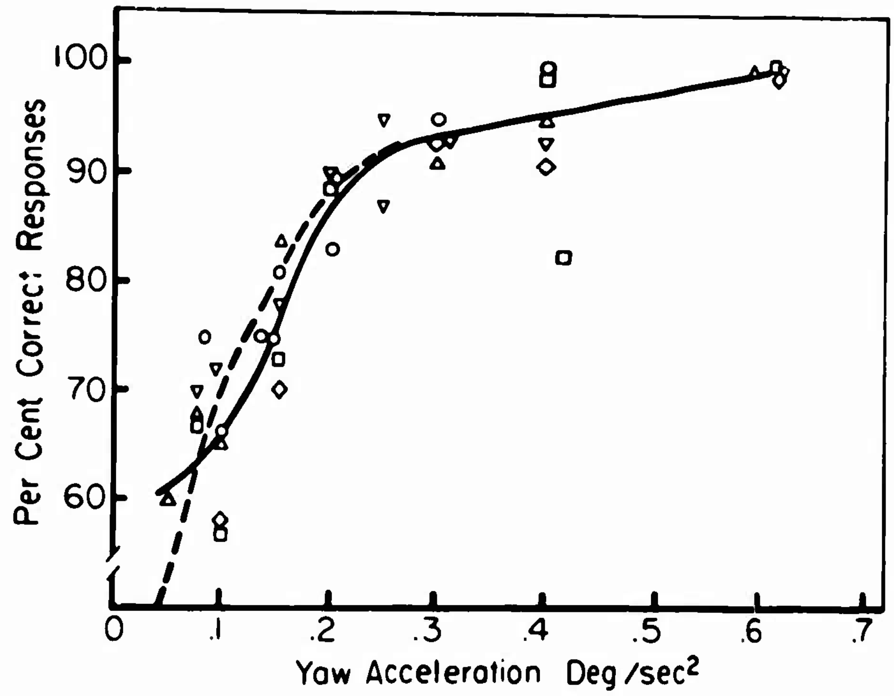


Figure 17. Perception of angular acceleration, indicated in terms of percent of direction-of-rotation judgments which are correct as a function of the level of angular acceleration. [The 75% point is considered to be the threshold point. (Redrawn from Clark & Stewart, 1962) Also included are the 75% points from the data of Man & Ray (1956)]

There are a number of illusions which are functions of certain types of acceleration exposures. Illusions may be defined as false or incorrect perception of one's position and motion. An example of an illusion was described by Astronaut John Glenn in his Friendship VII Mercury Capsule during his earth-orbital space flight. When the sustainer engine cutoff occurred and acceleration suddenly dropped to zero, he experienced a sensation of being tumbled forward. During prior training on the human centrifuge, Glenn and others had experienced this same sensation of apparent tumbling forward during sudden deceleration. Glenn reported that during the firing of his retro rockets during reentry preparations in his Friendship VII Mercury Capsule, he perceived the false sensation that he was suddenly accelerating in the reverse direction (Glenn, 1962).

There are several categories of illusions which result from angular and linear accelerations. Among the most interesting are the <u>oculogyral illusions</u>. They have their genesis in stimulation of the sensory receptors in the semicircular canals, and are described as

false sensations in which the visual field appears to be moving or spinning around a body axis. There are many varieties of oculogyral illusions, and some of them occur when the semicircular canals are stimulated by the onset or cessation of angular accelerations. Coriolis illusions occur when the head makes secondary rotations about an axis perpendicular to the primary axis of the rotation in which a pilot is being rotated. In a rotating room, for example, the rotation of the pilot's head out of the plane of rotation of the room produces an effect attributed to the coriolis accelerations which stimulate the semicircular canals.

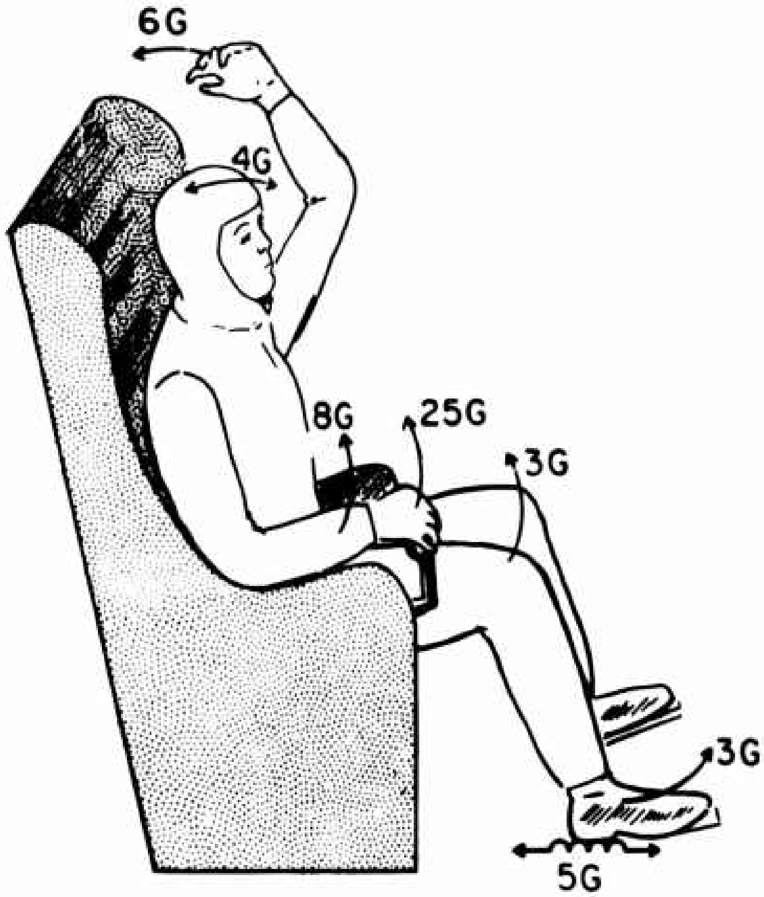
Vertigo is a commonly experienced illusion. It is a false sensation of rotation, or whirling around, in which the pilot feels as if the surroundings are revolving about him, or sometimes, as if he were revolving about his surroundings.

The oculogravic illusions are apparent tiltings or displacement movements which result from the stimulation of the otolith apparatus in the utricle of the inner ear. They result from linear, rather than angular, accelerations. During acceleration, a target may appear to be displaced upwards. Conversely, during acceleration, the target may appear to move downwards. On a centrifuge or rocket sled a pilot may experience a sensation of tilting backwards as he accelerates and forward as he decelerates. Some evidence suggests that the degree of perceived displacement corresponds to the angle between the resultant force and the normal force of gravity.

Major significance is given to illusions of motion and position, and their role in problems of spatial disorientation for space vehicles and for rotational space platforms is a matter of major controversy (Chambers, 1964).

EFFECTS OF ACCELERATION ON DISCRETE MOTOR RESPONSES

In addition to influencing the pilot's ability to perceive stimuli, acceleration modifies his ability to respond to them. Figure 18 shows motor movements which are just possible at the indicated accelerations. The motor responses indicated in this figure are gross body movements, and movements of the arms and feet. In most instances we are more interested in the type of movement in which the pilot makes a discrimination and responds by operating the appropriate lever or switch from a number of alternatives. Generally it is agreed that acceleration influences discrimination response time. Figure 19 summarizes some discrimination response times which were obtained in more than 900 acceleration exposures up to $+8\ G_x$. The figure shows that transverse acceleration had a significant effect upon discrimination reaction time, showing a steady increase from approximately 0.23 sec at $0\ G_x$ to 0.33 sec at $+8\ G_x$.



MOVEMENT OF THE BODY, AS INDICATED BY THE ARROWS, IS JUST POSSIBLE AT THE VEHICLE ACCELERATIONS LISTED

Figure 18 Movements just possible under conditions of vehicle accelerations

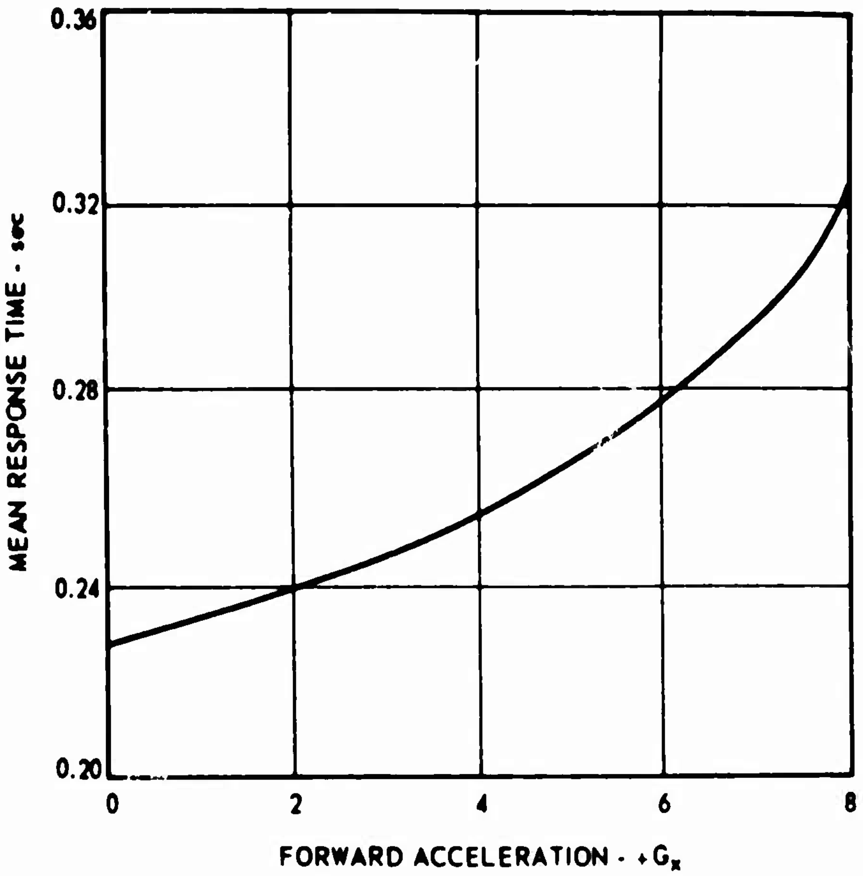


Figure 19. Mean response times obtained in more than 900 G_x accelerations (Kaehler and Meehan, 1960)

It has not been possible to identify all of the underlying mechanisms which mediate these effects. During acceleration, the changes observed in reaction time may be associated with pilot impairment in a variety of physical loci. Acceleration may reduce the capacity of the peripheral system to receive the stimulus, or the central nervous system to process already received stimuli and to indicate discriminatory choice, as well as reduce the ability of the neuromuscular system to coordinate the motor components which translate the response into the manipulation of the appropriate control device.

At AMAL, a discrimination reaction time test apparatus was developed which consisted of a small response panel containing four small stimulus lights, a small response handle containing four small response buttons, and a random programmer device which could present a large variety of stimulus sequences to subjects on the centrifuge (Chambers, Morway, et al, 1961). As each of the lights came on, the subject was required to press the associated button with the appropriate finger of

his right hand as fast as he could. Both the automatic program, which activated the stimulus lights, and the subject's responses were fed to an analog computer where initial data reduction of response times and accuracies were performed. Following pre-acceleration training to establish a stable base-line performance level, each subject received three blocks of 25 trials each when exposed to $+6\ G_x$ for five minutes. Each subject received three acceleration trials. The results, showing data in terms of normalized and added times and errors, are presented in Figure 20. The figure shows a highly significant effect of G_x acceleration on discrimination reaction performance, not only during the runs, but also within the 5-minute post-test period. Recent experiments have suggested that this post accelerative effect may be related to the blood oxygen saturation level drop which occurs during acceleration and recovers slowly following termination of the acceleration stress.

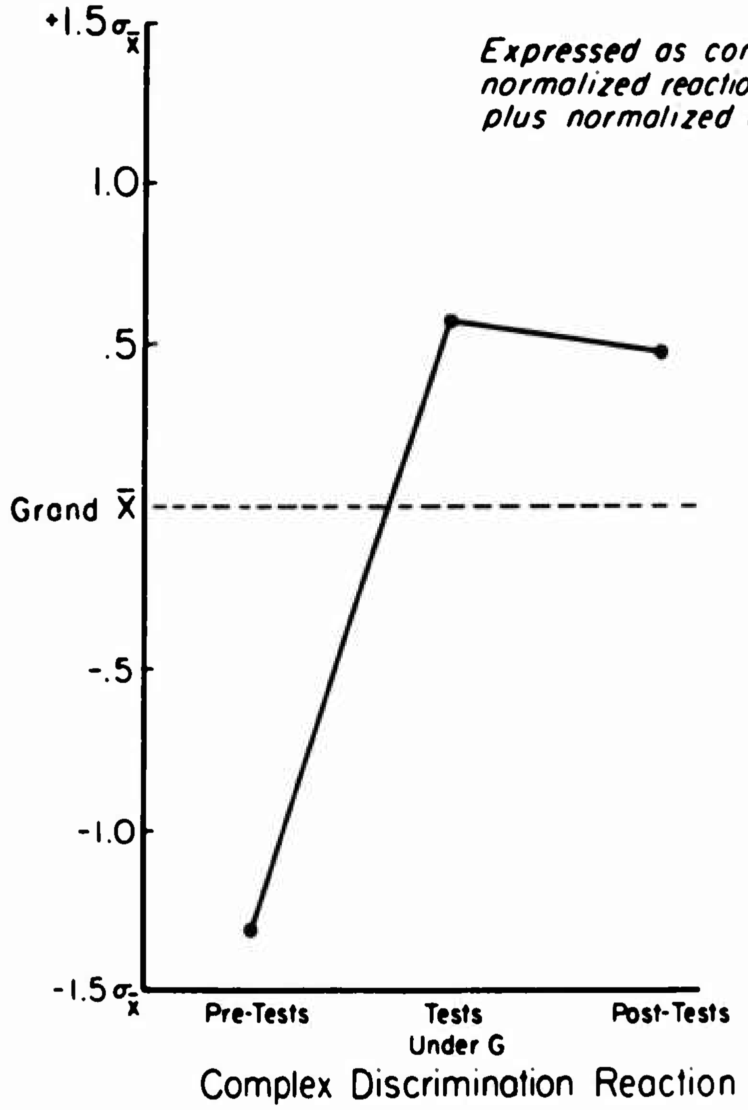


Figure 20. Complex discrimination reaction time performance during exposure to 6 G_x for 5 minutes per run

Another type of discrete motor response behavior which has been studied extensively has been the pushing and pulling behavior which a pilot makes when he changes the direction of force which he applies to the control stick when performing a continuous tracking task. We refer here not to the smooth tracking behavior itself, but to the stick reversals which the pilot makes as he performs. This is highly susceptible to the effects of acceleration. For example, in Figure 21, the results of a study are presented in which 9 pilots were exposed to accelerations associated with turbulence conditions as they attempted to operate a two-dimensional tracking task. The results present the average number of control stick reversals which these pilots performed under static and dynamic conditions. A highly significant effect of acceleration was found. The details of this experiment, as reported by Ragland, Chambers, Crosbie, and Hitchcock (1964), present an example of the marked effects of low level accelerations (-1.5 to $+3.1G_z$) associated with turbulence on control stick reversal performance.

CONTINUOUS PSYCHOMOTOR RESPONSES: TRACKING PERFORMANCE

Acceleration has significant effects on continuous psychomotor responses, such as are required in performing tracking tasks. An example of the severe effects which high transverse acceleration stress may have on tracking is shown in Figure 21. In this figure, the time-on-target scores dropped from approximately 94% at 1 G_x to approximately 12% at 16.5 G_x and returned to approximately 96% when the run was terminated (Clarke et al, 1959).

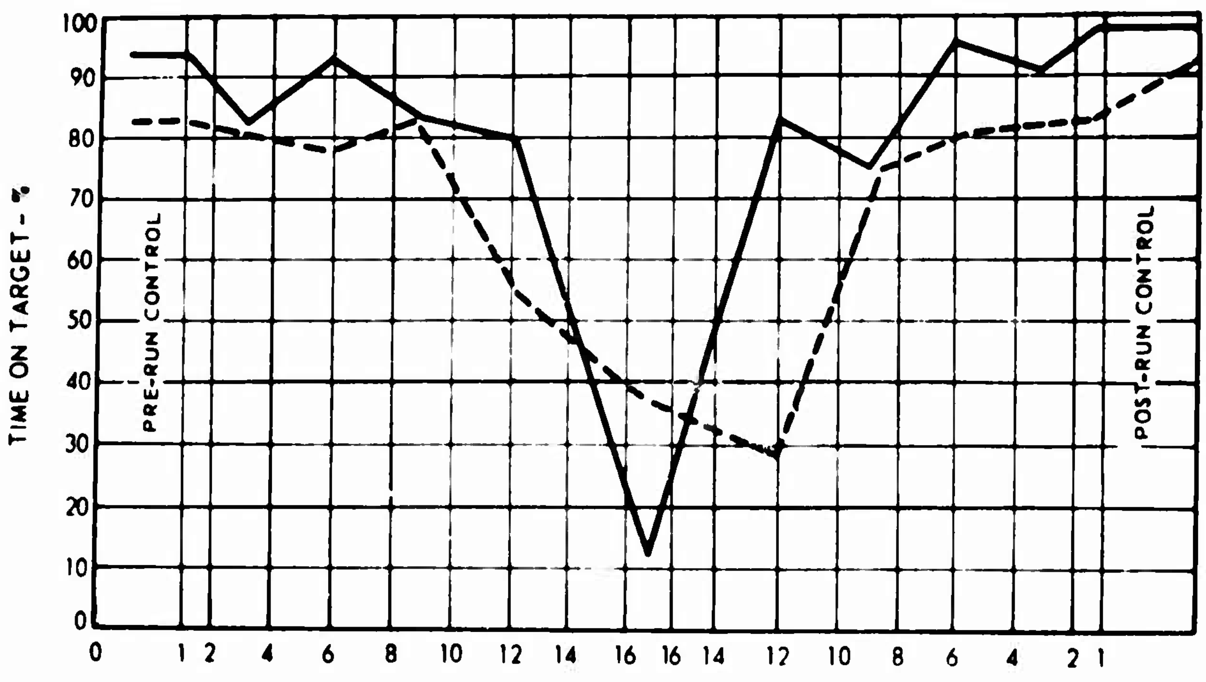


Figure 21. Example of decrement in tracking performance during exposure to a 16 G_x profile. [A 3.5 mm target was used in a dual pursuit task by each of the two subjects (Clark et al 1959)]

The amount of error which a pilot accumulated during exposure to positive acceleration is much greater than that which he accumulated during exposure to transverse acceleration. An example of this is presented in Figure 22 in which the relative error magnitudes for a group of pilots are plotted as a function of $+G_x$ and $+G_z$ acceleration magnitudes. The figure clearly shows that under conditions of transverse acceleration the pilot may accumulate significantly less error at higher acceleration magnitudes. Similar data are presented in Figure 23, in which mean tracking error obtained by 12 test pilots is plotted as a function of $+G_x$, $-G_x$ and $+G_z$ accelerations.

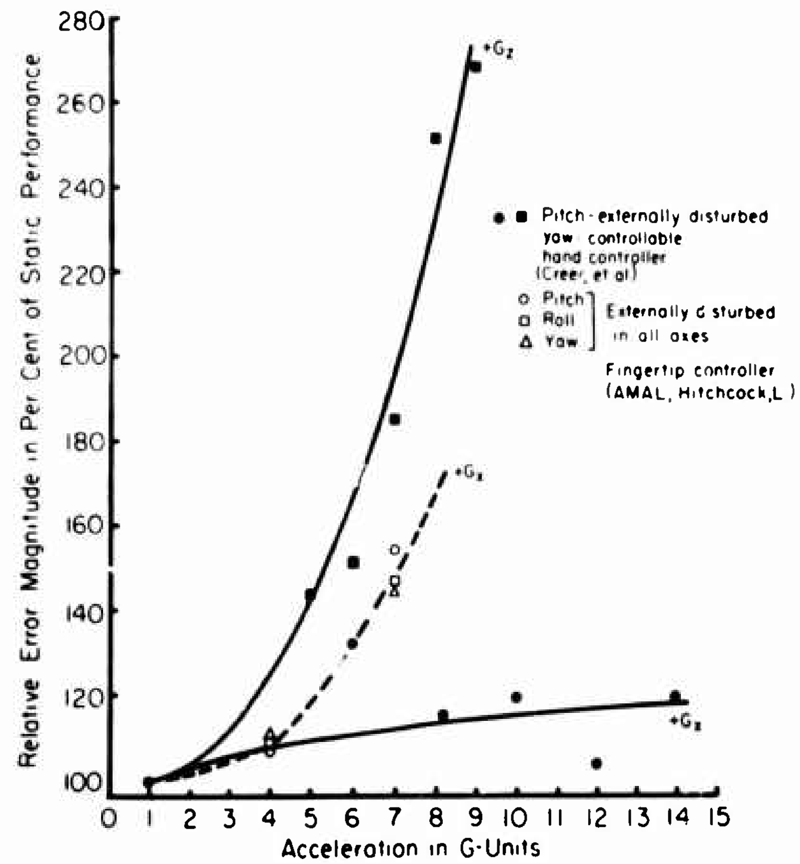


Figure 22. Performance as functions of the magnitude and vector of acceleration exposure. [The solid points represent a replotting of data obtained on the AMAL Human Centrifuge by Creer and Douvillier (1962), in which pilots used a two-axis hand controller, and a task in which the programmed disturbances were introduced into the pitch axis only, but in which yaw error introduced by the pilot also contributed to the overall piloting task. The open points represent unpublished AMAL data in which disturbances were introduced into all three axes by the computer, and compensatory control was effected by the pilots through a three-axis finger tip controller]

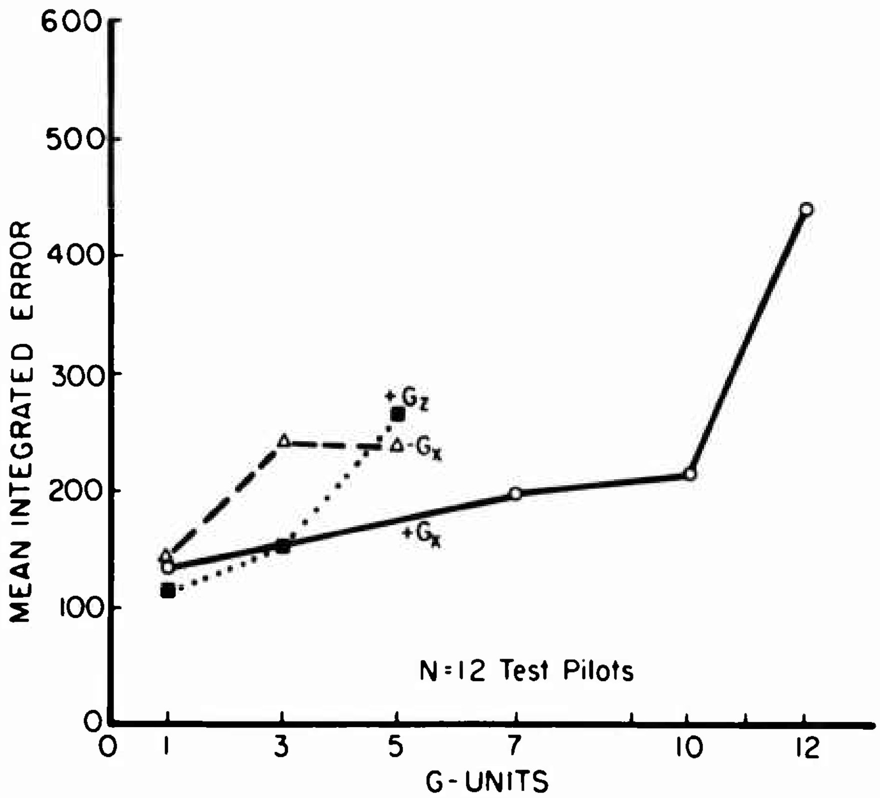


Figure 23. Mean integrated tracking error for G_X, $-G_X$, and G_Z accelerations for 12 test pilots during sustained tests on the AMAL Human Centrifuge

Studies of tracking performance during staging acceleration profiles, such as may be characteristic of certain two-stage and four-stage launch vehicles, have suggested that at the higher acceleration levels, pilots find it extremely difficult to concentrate on all aspects of a complex task while they are exposed to high acceleration loads, whereas at the lower acceleration levels they can perform very well. Figure 24 presents examples of this condition, in which pilots performed exactly the same tasks statically and dynamically for each of two types of booster combinations. The pilot's task was to perform the four aspects of the task continuously so as to fly the vehicle through the orbital injection "window". For both types of vehicles, it was found that the pilots made significantly more errors on the yaw quantity during dynamic conditions than during static conditions, but that they were able to maintain the other three task components very well under both dynamic and static conditions. In this particular study, the accelerations did not exceed 7 G_X for either type of vehicle.

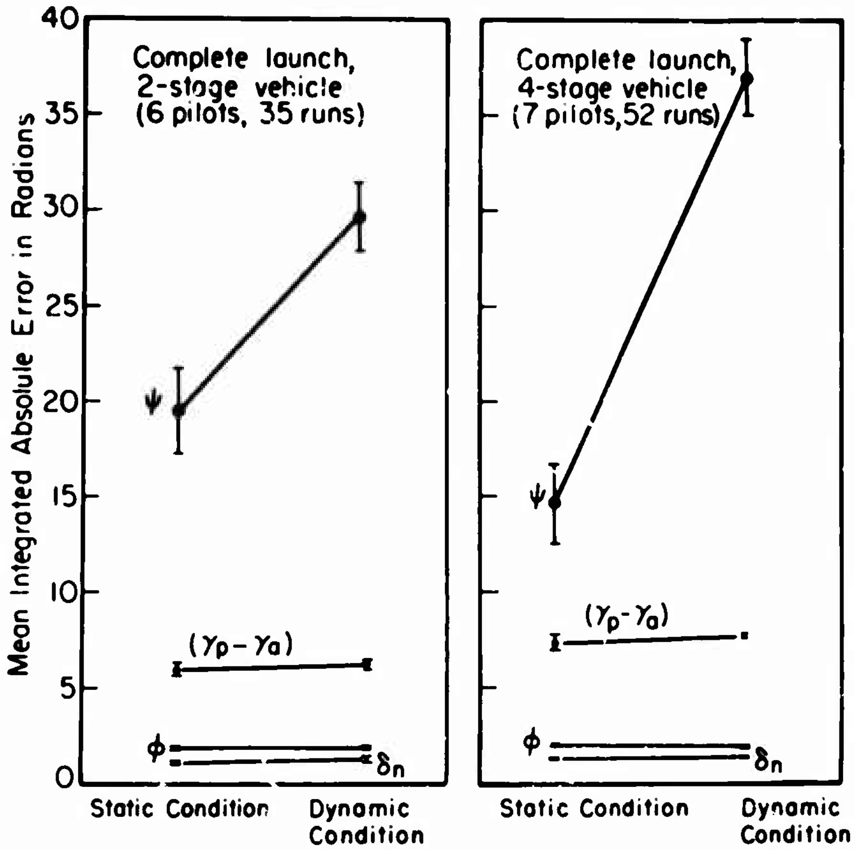
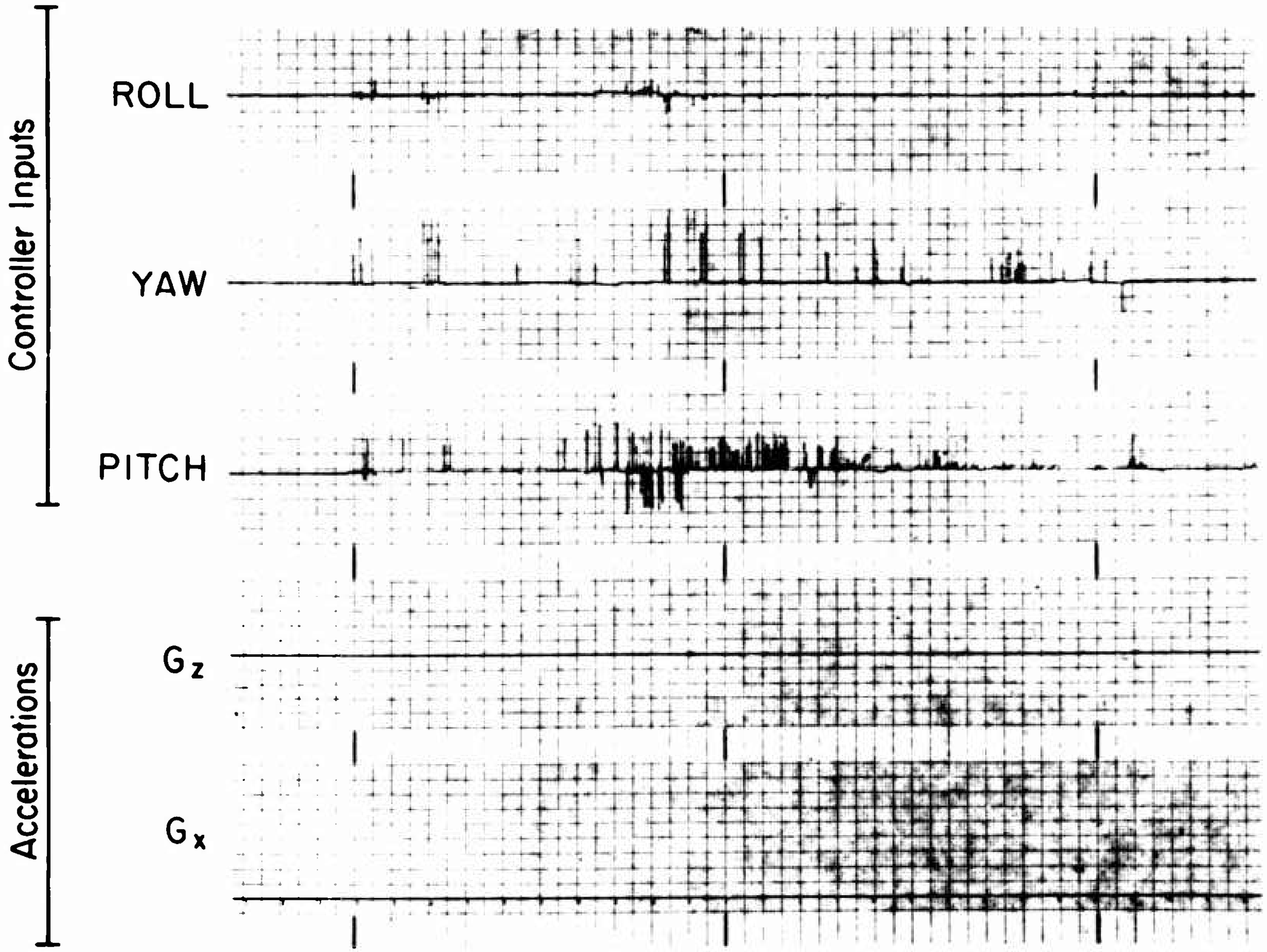


Figure 24. Static vs. dynamic pilot performance for 2-stage and 4-stage vehicles, as simulated on the AMAL centrifuge. (The pilot's task was to perform complete launch maneuvers)

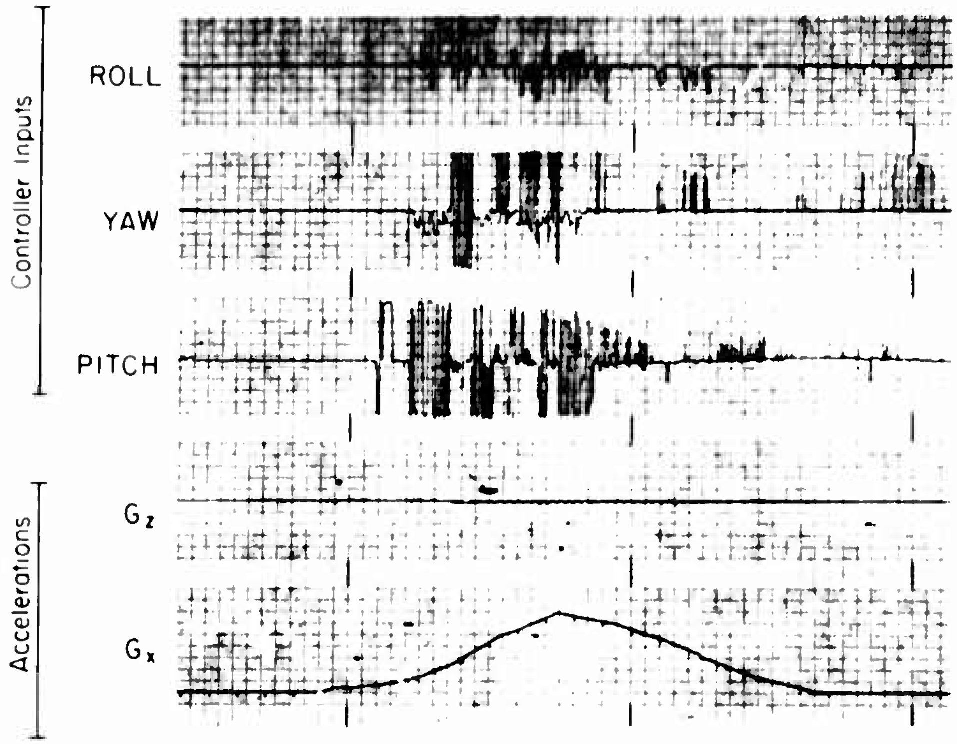
It is interesting to compare the performance of a single astronaut who performs the same task on the centrifuge both statically and dynamically. Figures 25 and 26 present such a comparison. The most marked difference noted between the static and dynamic conditions is during the time when the astronaut was performing the reentry task. Some impairment of performance is shown, and this is attributed to the acceleration.

During reentry simulations of the Atlas vehicle on the human centrifuge inadvertent control inputs are not uncommon. These inadvertent inputs often mirror the acceleration profile under which a control task is being performed. Figure 27 shows an actual record of this, illustrating inadvertent control inputs in the roll and yaw axes, using a Mercury-type controller.



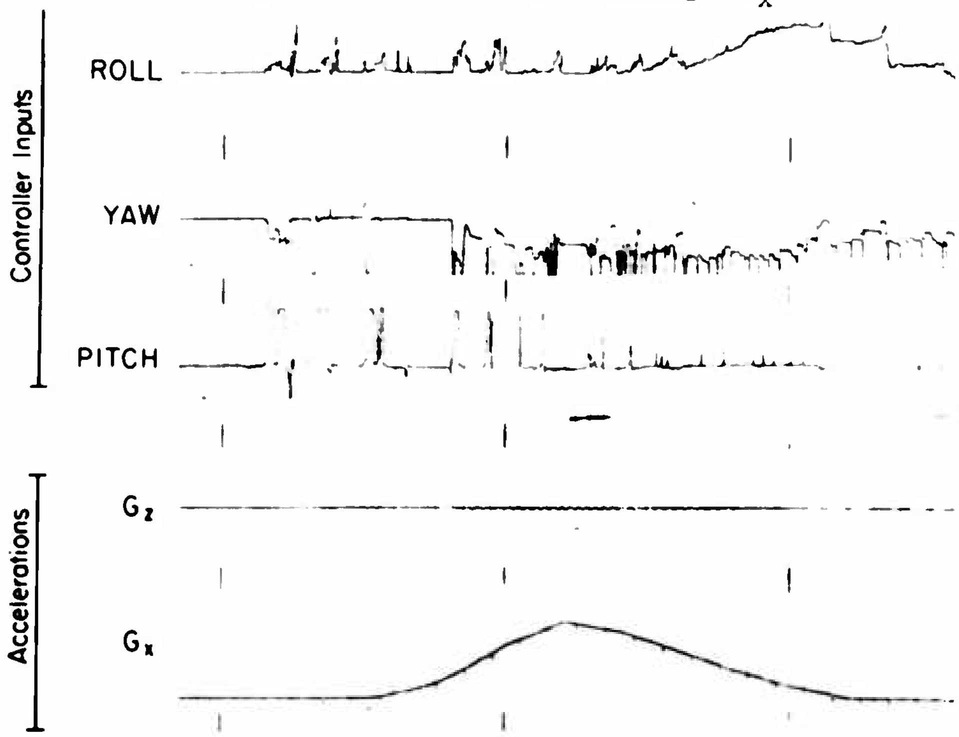
Sample Performance Under Static Conditions

Figure 25. Recording of sample performance under static conditions. (Compare with Fig. 26)



Performance of the Same Pilot Under Dynamic Conditions

Figure 26. Recording of performance (of the same pilot as shown in Fig. 25) under dynamic centrifuge simulation conditions reaching 8 G_X



Simultaneous Inadvertent Inputs in the Roll and Yaw Axes

Figure 27. Recording of simultaneous inadvertent control stick inputs in the roll and yaw axes during exposure to an 8 G_X profile

In addition to inadvertent control inputs which frequently accompany acceleration stress, other more general effects of dynamic conditions may be observed. Acceleration reduces the sensitivity and timing of all controller movements. Sometimes, it appears that all stimuli appear to have an apparent equivalence to the subject during high G stress as is indicated by the stereotyping of responses at 15 G_x illustrated in Figure 28. In this example the pilot performed a simple two-dimensional tracking task during exposure to accelerations reaching +10 G_x and + 15 G_x.

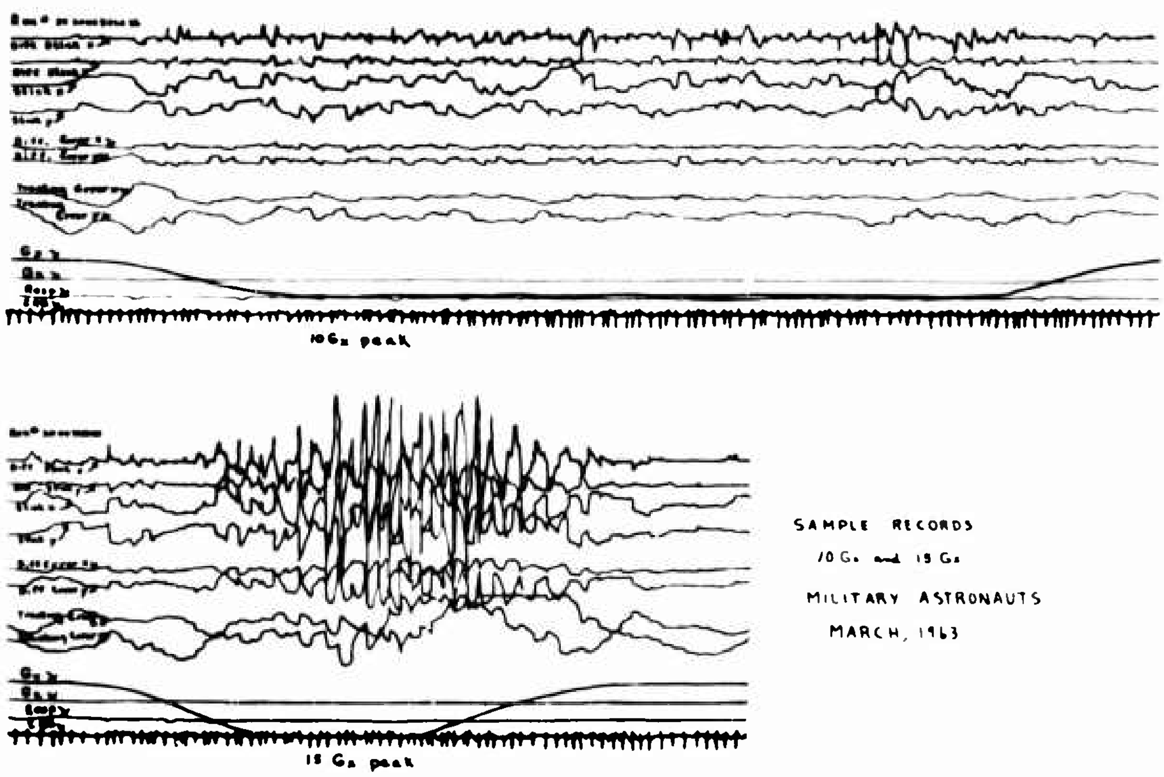


Figure 28. Sample recordings of piloting performance during exposure to 10 G_x and to 15 G_x on the human centrifuge

Hundreds of acceleration tests have been conducted on astronauts, test pilots and other volunteer subjects. During these tests in which the effects of high acceleration stress on piloting performance have been intensively studied, rather specific characteristics of piloting performance impairment have been observed. These may be summarized as follows:

a. Increase in error amplitude as G duration and amplitude increases.

b. Lapses, or increasing unevenness and irregularity in task performance.

c. Performance oscillations.

d. Falling off or reduction in proficiency on some parts of a task while maintaining proficiency on other parts.

e. Changes in phasing and/or timing task components.

f. Inadvertent control inputs.

g. Failure to detect and respond to changes in the stimulus field.

h. Errors in retrieving, integrating, storing and processing information.

i. Changes in the rate of performance, such as sudden initiation of performance nonessential to the task.

j. Response lags and errors in timing. Increases in latency of response to discrimination stimuli. Also, there may be large changes in timing of component response sequences, or gross misjudgments of the passage of time.

k. Overcontrolling or undercontrolling, as during a transition phase.

l. Omission of portions of simple tasks, or of parts of complex perceptual motor tasks. These occur especially during overload when the subject may not process all of the stimulus information, such as the inputs necessary to perform the secondary parts of the task at the originally achieved level of proficiency.

m. Approximations. The pilot's behavior becomes less accurate, although the task does not increase in difficulty level. His responses become less precise, but minimally adequate to meet the required criterion of proficiency.

n. Stereotyping of responses and movements, regardless of the stimulus situation. All of the stimuli appear to have an apparent equivalence to the subject during prolonged stress.

EFFECTS OF ACCELERATION ON HIGHER MENTAL FUNCTIONING

It is generally accepted that exposure to high or prolonged acceleration may produce confusion, unconsciousness, disorientation, memory lapses, loss of control of voluntary movements, or prolonged vertigo. However, to date, there are very few quantitative data regarding the effects of acceleration on specific intellectual functions. At AMAL, emphasis in this area has been concentrated on immediate memory, since an astronaut or scientific observer during some phases of flight may be required to perform such tasks as monitoring, reporting, memory, and processing of information, all of which require immediate storage or memory of information.

Ross, Chambers, and Thompson (1963) developed a continuous memory testing apparatus which could be used on the AMAL centrifuge. It required the continuous and repetitive memorization of a portion of a sequence of random symbols. As each symbol occurred, the subject was required to compare it with his memory of the symbol that had been presented to him two, three. or four presentations previously. New symbols appeared continuously, so that the subject constantly had to forget earlier symbols as he added new ones. Approximately 50 symbols were presented for each of the runs. In the earlier study, each run stayed at +5 G_x for five minutes. The data, collected on 21 subjects, indicated that the subjects could continue to perform this task just as well during exposure to +5 G as they could statically. Subjectively, the subjects reported that their performance deteriorated under G and that they generally regarded +5 G_x for five minutes as a stressful experience. However, subjects tested in the centrifuge gondola did more poorly than subjects tested in a regular testing room. The implication seems to be that some apprehension or anxiety may have been acting to interfere with maximum performance.

Ross, Chambers, and Thompson (1963) developed a task which required the subject to monitor two small display tubes which were located directly in front of his normal line of vision. The left-side tube presented numbers, and the right-side tube presented plus and minus symbols. The task was to continuously make matches for these two presentations simultaneously as the runs proceeded and to select one of two buttons to indicate whether both the number and symbol which were appearing were the same as or different from those which had occurred on a specified number of trials previously. Acceleration loads of 1, 3, 5, 7, and 9 G_x were studied. Each test was 2 minutes and 18 seconds long. The results of the experiment suggested that proficiency in immediate memory was maintained at least through 5 transverse G. However, at +7 and +9 G_x, some impairment of immediate memory was observed. The results of this experiment are shown in Figure 29.

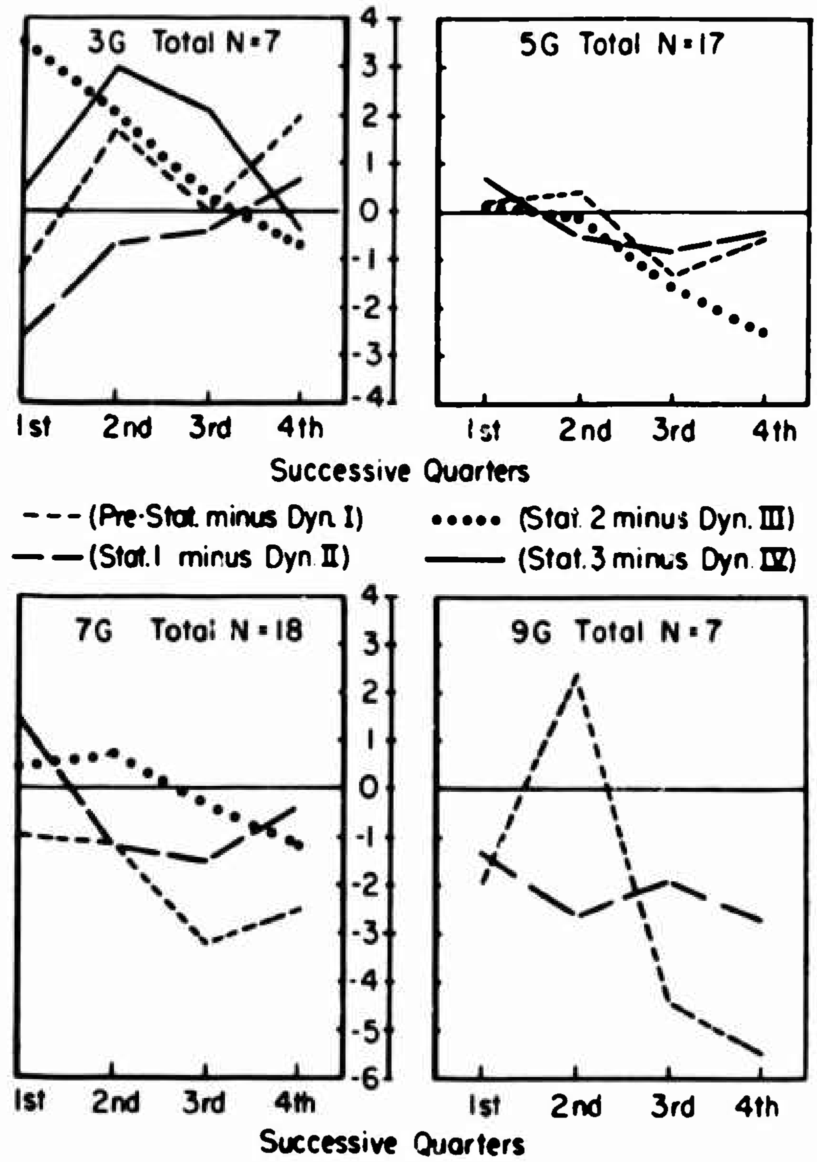


Figure 29. Successive quarters scores for 3, 5, 7, and 9 G_x, showing performance on immediate memory task. (Ross, Chambers, and Thompson, 1965)

During prolonged exposure to acceleration, the continuous concentration necessary for performance is difficult, fatiguing and boring. For example, during an extended 2 G centrifuge run which lasted 24 hours, the subject started out with a somewhat detailed set of procedures to follow in making medical observations upon himself, recording his subjective comments, and writing and typing (Clark and Hardy, 1959). However, the subject found that in spite of his initial high resolves he took naps and listened to the radio and suffered primarily from boredom and fatigue.

Areas of contact with the chair in which he was seated were the sources of the greatest localized discomfort. At 16 hours elapsed time, the subject reported the onset of aesthenia of the ring and little finger and outer edge of the palm of the left hand. The subject found it impossible to maintain his originally prescribed maintenance and observation schedules.

Chambers and Ross secured a subject in a Mercury-type contour couch and required him to perform the two symbol running matching memory task (previously described) every 10 minutes for four and one-half hours. The subject was able to perform this task throughout the entire period with only minor performance impairment. The results of this experiment are shown in Figure 30.

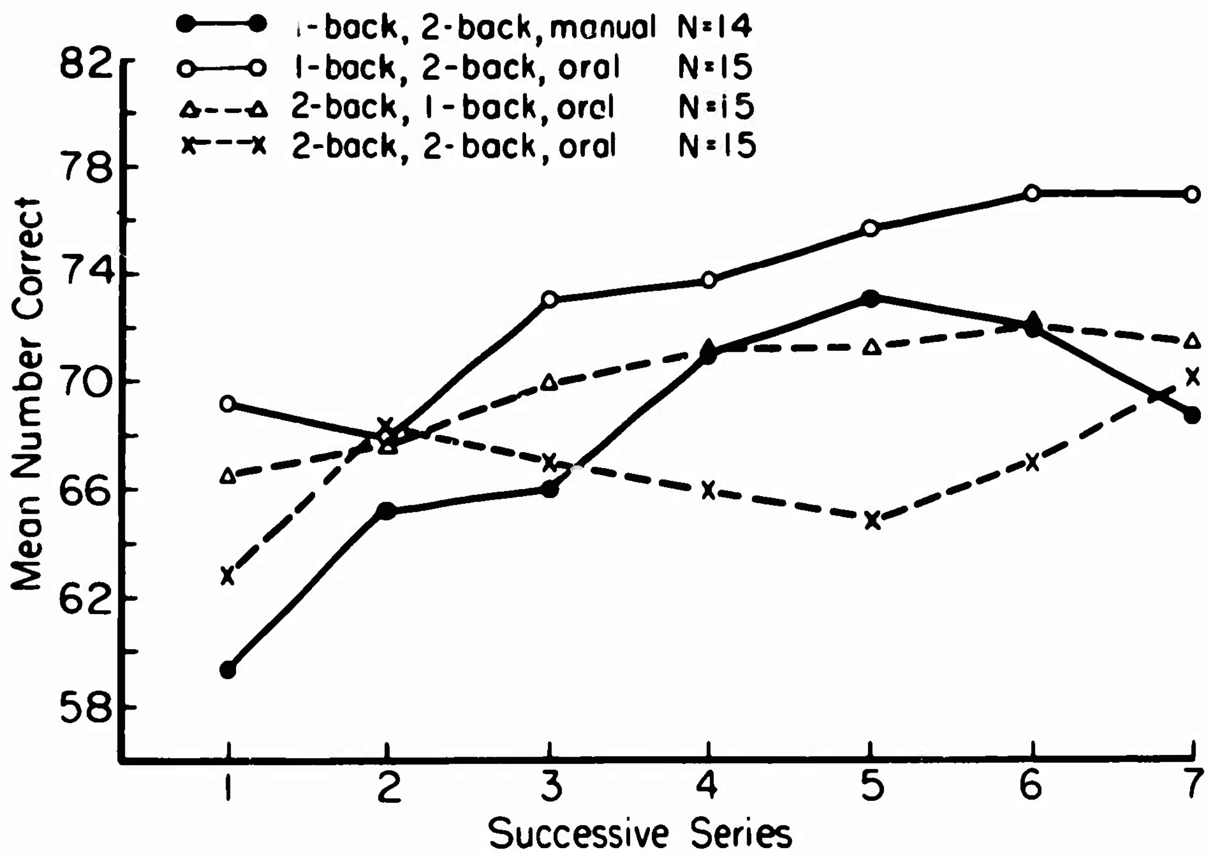


Figure 30. Mean number correct as a function of successive four-series blocks for 1-back and 2-back immediate memory task responses during a 4-1/2 hour centrifuge run at 2 G_x

EMOTIONAL BEHAVIOR, FEAR, AND ANXIETY

It is a common observation that both the anticipation and occurrence of acceleration forces contribute to anxiety and other types of emotional behavior. As far back as 1946, Hallenbeck, Wood, Lambert, and Allen found that pulse rates were approximately 10 beats faster per minute during the interval just prior to G than during the G itself. The increase in pre-acceleration pulse rate is a psychological effect. Brown, Ellis, Webb, and Gray (1957) have demonstrated that during a series of centrifuge runs going as high as 12 G_X the pulse rates of the subjects immediately prior to exposure to the acceleration were faster than during the acceleration run itself. This increase in pre-acceleration pulse rate was highly significant for all subjects. In the case of subjects who had had some prior experience on the centrifuge, the pulse rate varied according to the G-level which was anticipated. (One of the most consistent effects of acceleration itself is an increase in pulse rate, and there seems to be some suggestion that the increment may have been due to cardiac conditioning rather than to anxiety.)

Laboratory experience indicates that naive subjects undergo significant changes in pulse rate, blood pressure, and GSR in anticipation of the start of high G exposure. However, these changes become minimized following repeated exposures to acceleration. The question has been raised concerning the effects of high acceleration on the galvanic skin response, a measure that is frequently used as an indicator of emotional behavior. Significant effects of high transverse acceleration on GSR have been observed at the AMAL human centrifuge, but it has not been possible to interpret the results of GSR recordings, since they were unlike responses generally obtained during anxiety provoking situations at 1 G_X.

In most instances, it is not possible to make quantitative measures of emotional behavior immediately before, during or after these centrifuge exposures, because of the extensive number of other engineering and physiological tests which are required, and because there are no good quantitative measures of emotionality which may be used on the centrifuge.

A recent experiment conducted by Chambers and Lathrop on the AMAL human centrifuge has suggested that pharmacological agents may be used to effectively improve tracking performance during exposure of naive subjects to acceleration stress. A sample of 32 subjects received three 3 G_X runs, three 6 G_X runs, and eight 1 G static runs. The sample was divided into four groups prior to centrifugation: a depressant group, which received 3/4 grain of seco-barbital; a tranquilizer group, which received 400 mg of meprobamate; an energizer group, which received 10 mg dextro-amphetamine, and a control group, which received a placebo. The results of the experiment are presented in Figure 31. This figure presents the relative amounts of error performance obtained by each of the four groups. The figure suggests that the depressant group showed the smallest amount of error, whereas the energizer group showed the most

error, and the placebo and meprobamate groups were intermediate. The results of this experiment, though preliminary, suggest the possible value of biochemical agents in assisting the naive subject in being calm and relaxed during his early exposures to acceleration stress.

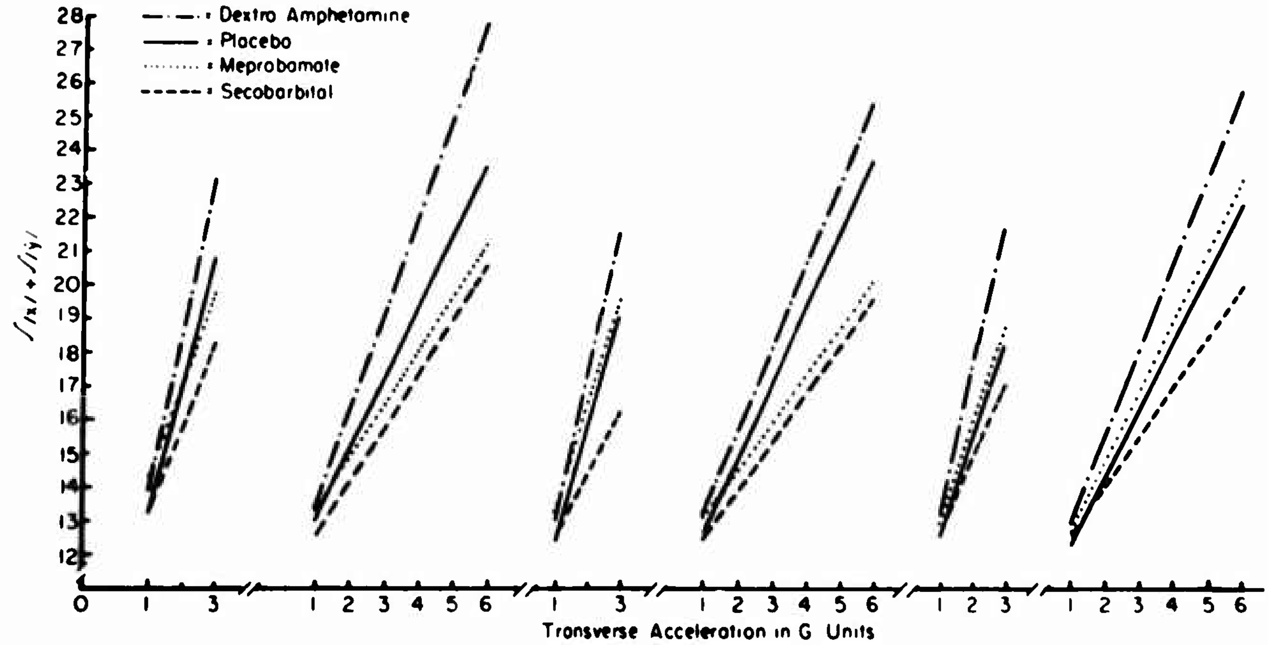


Figure 51. Relative amounts of tracking error in four groups of subjects following administrations of dextro-amphetamine (10 mgs), meprobamate (400 mgs), seco-barbital (3/4 grain), and placebo (control). [It is postulated that acceleration protection may be provided by certain types of pharmacological agents]

PROTECTION AGAINST THE EFFECTS OF ACCELERATION

In addition to the concepts of physiological and performance G tolerance, an important concept is that of G-protection. There are many kinds of G-protection, including form-fitted contour couches, net couches, G-suits, water suits, a large variety of straps, restraints, bindings, and foams. The standard type of G-protection for positive ($+G_x$) acceleration is the G-suit. As G increases, the suit inflates around the legs and torso, and the resulting pressure thereby assists in maintaining blood in the head region, thus assisting the pilot in maintaining vision and consciousness. Whereas this system is helpful for positive acceleration ($+G_z$), it does not provide protection from transverse accelerations ($+G_x$ and $-G_x$). Transverse supine accelerations have been used in Project Mercury, and they are planned for Project Gemini and Project Apollo.

Consequently, there is a major interest in protecting pilots against the effects of transverse supine ($+G_x$) accelerations.

The G-protection system used most frequently for transverse acceleration is the form-fitted contour couch. During the past five years, AMAL, working closely with NASA, has been instrumental in developing and testing a variety of contour couches which could be used for operational use. A family of these couches is shown in Figure 32. Each couch is individually molded for a specified person. The one at the far left was developed in cooperation with the NASA High Speed Flight Center at Edwards Air Force Base, California, and was found to be satisfactory for acceleration loads extending to +15 G_x during which time the pilot was required to fly complex two-stage boost-orbital missions. The second couch was a design developed for the Mercury Astronauts and this particular couch for Astronaut Carpenter permitted acceleration runs to +14 G_x. Some of the astronauts who were fitted to these couches achieved runs to 15 G_x. These couches were developed in cooperation with NASA Langley Research Center.

Figure 32. Examples of individually molded contour couches used in pilot performance studies

In the center is a couch developed in cooperation with the NASA Ames Research Center. The primary feature of this couch was that the feet could be freed so as to allow the pilot to use toe pedals. Pilots have successfully used couches of this type to as high as $+14\ G_x$ without losing control of relatively complex piloting tasks. The fourth couch represents a model which was developed for permitting the use of the Mercury full-pressure suits. This model of couch was used in most of the centrifuge acceleration training projects for the Mercury Astronauts. These couches were developed in cooperation with NASA Langley Research Center and the McDonnell Company. The last couch represents the final design used in some of the centrifuge training programs for the Mercury astronauts, showing slight additions of an inner liner and slightly modified head support. This couch design was used in the early Mercury flights, and has been found effective for tolerating acceleration loads up to $14\ G_x$ without loss of control of a relatively complex reentry task.

Other types of acceleration protection include the net couch, and the water G-capsule. An example of the net couch is shown in Figure 33. A comparative evaluation of the maximum tolerable acceleration profiles which have been sustained using these types of acceleration protection is presented in Figure 34. Also, more detailed data are presented in Figure 35.

Armstrong (1959) and Watson and Cherniak (1961) have suggested that providing a pilot with positive pressure breathing of 100% oxygen during acceleration stress, especially sustained transverse acceleration, increases endurance time.

Watson and Cherniak (1962), using positive pressure breathing of 2-1/2 to 3 mm Hg per G, found that a 67% increase in tolerable duration of exposure to $10\ G_x$ transverse G could be produced. This study utilized 100% oxygen, rather than normal breathing air. Oxygen uptake itself has been found to increase duration time. Chambers, et al (1962), using a brightness discrimination apparatus, conducted an experiment to determine whether positive pressure breathing of 100% oxygen would facilitate brightness discrimination during steady-state accelerations. The subjects operated a pressure breathing oxygen regulator manually so as to provide 0.7 inches of mercury per transverse G on the centrifuge. The subjects performed under three breathing conditions: breathing normal air, 100% oxygen, and 100% oxygen under positive pressure. Given a background luminance of .03 foot-lamberts, the subjects were required to repetitively operate a switch to maintain the target at the minimally discriminable brightness contrast level. The results are shown in Figure 36. The contrast required for discrimination appeared to be the same for both the 100% oxygen and 100% oxygen plus positive pressure breathing. Both of these conditions were superior to the normal breathing air condition. It is interesting to note that as acceleration increased, the percentage of subjects reporting beneficial effects from the positive pressure breathing of 100% oxygen increased, as compared with the other conditions.

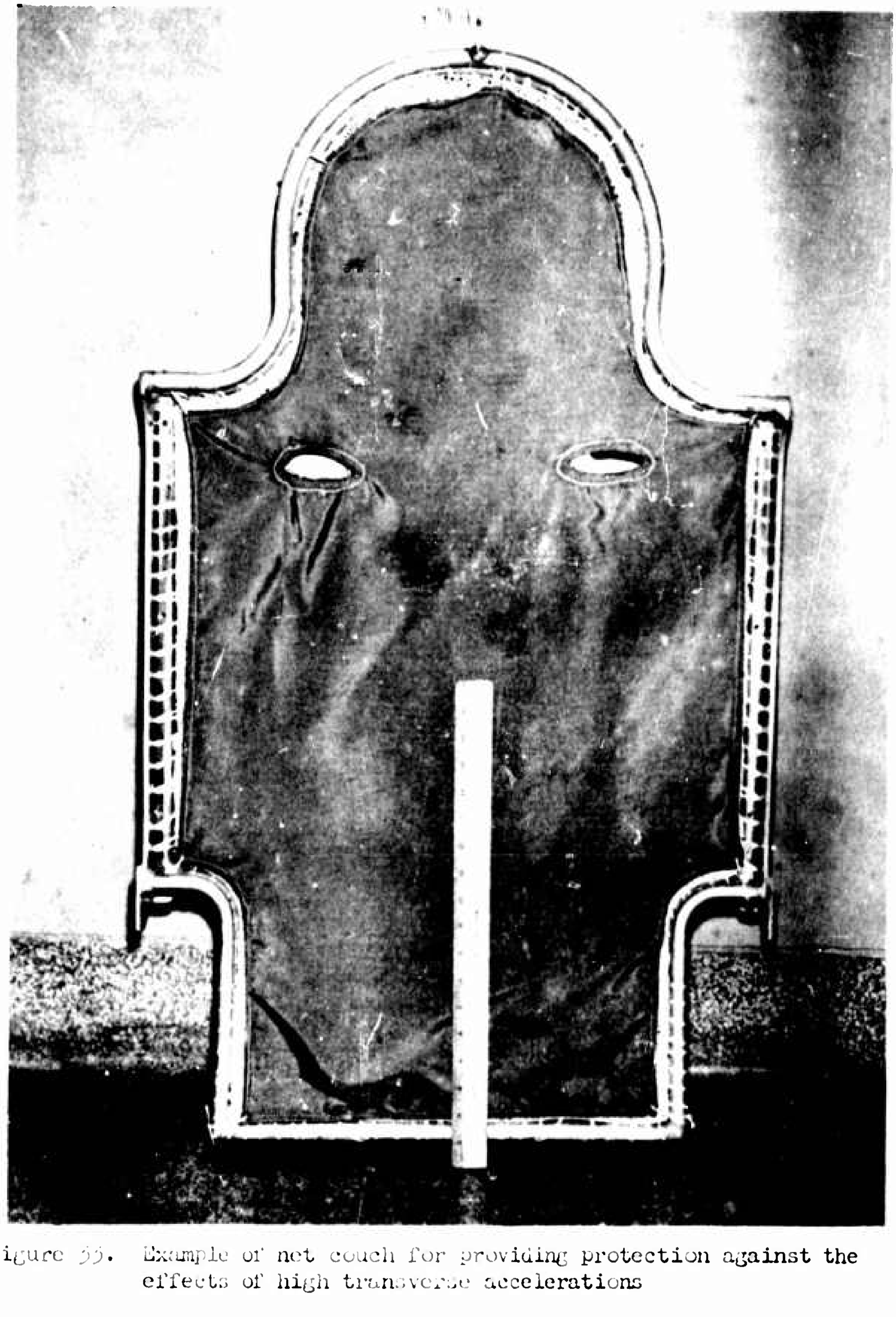


Figure 55. Example of net couch for providing protection against the effects of high transverse accelerations

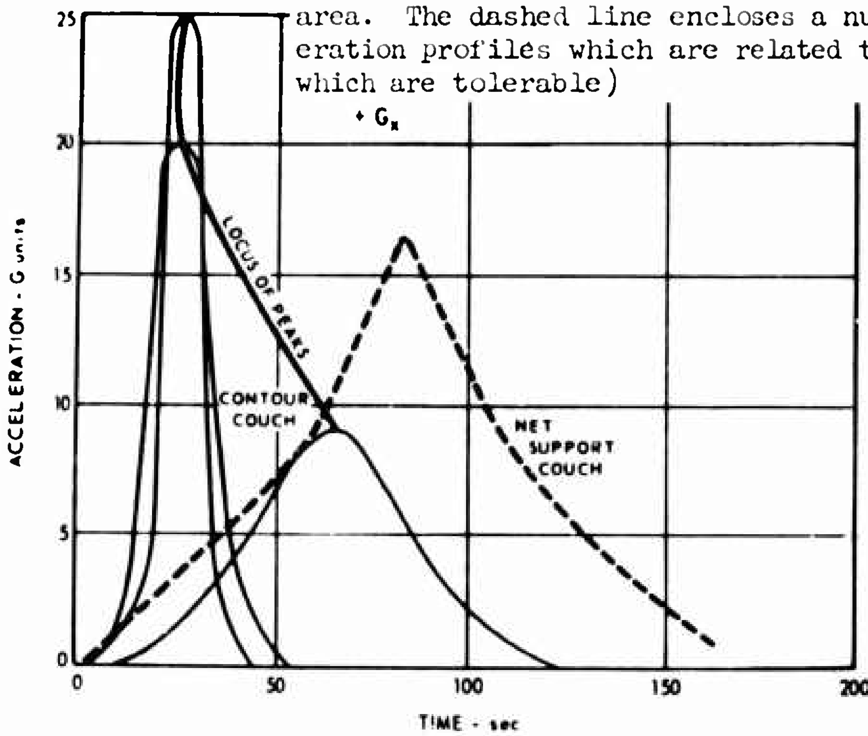


Figure 34. Maximum tolerable acceleration profiles. (The figure shows the greatest acceleration time histories that have been tolerated on centrifuges, using both special acceleration protection devices and positioning. The solid lines show three curves which define about the same area of G_X times time. A heavy line connects the peaks of these three curves, and locates the peaks of other curves enclosing the same area. The dashed line encloses a number of possible acceleration profiles which are related to space flight, all of which are tolerable)

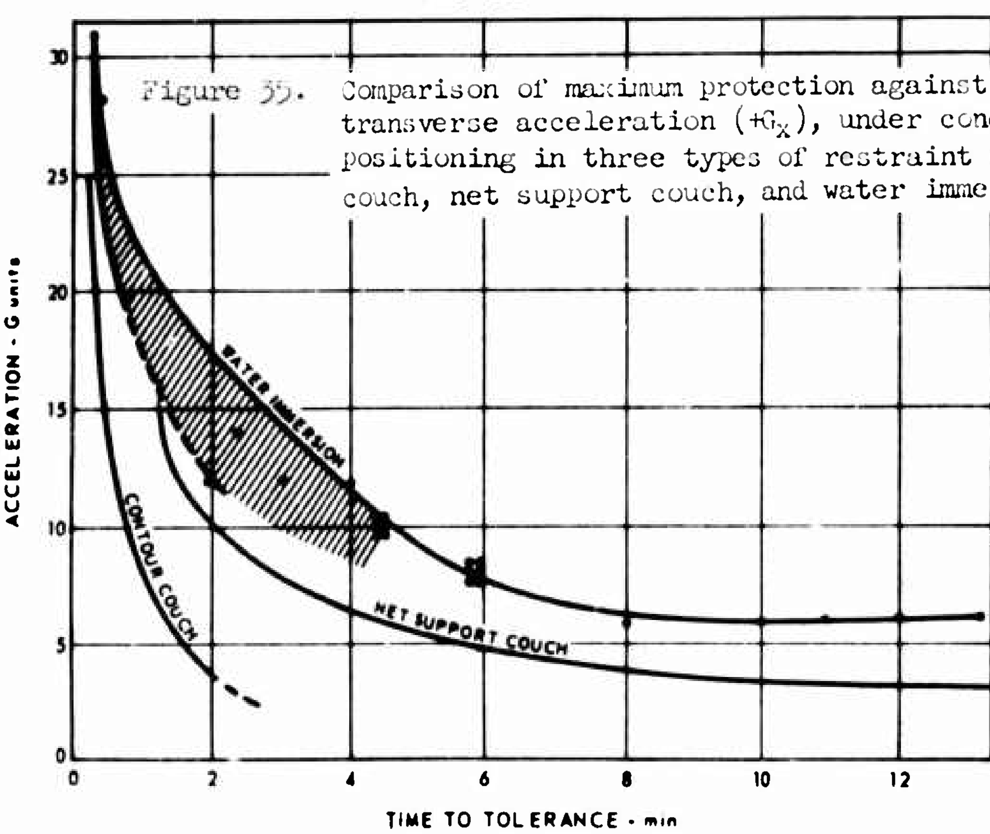


Figure 35. Comparison of maximum protection against the effects of transverse acceleration ($+G_X$), under conditions of optimal positioning in three types of restraint systems: contour couch, net support couch, and water immersion

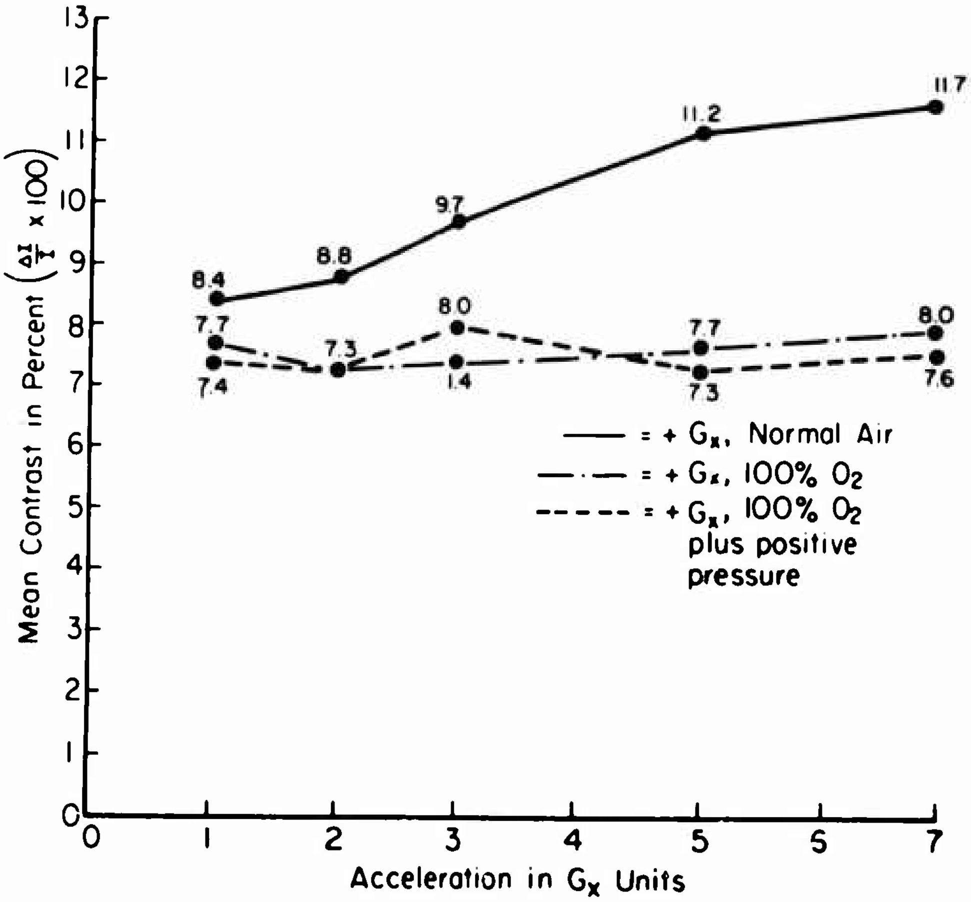


Figure 36. Comparison of effects of breathing normal air, 100% oxygen, and 100% oxygen plus positive pressure, on brightness contrast requirements (As measured on the AMAL Human Centrifuge)

A similar study was conducted on test pilots at much higher acceleration loads using peak acceleration centrifuge runs of 8, 10 and 12 G_x. The pilots performed a Mercury type reentry task, with the centrifuge at a steady-state acceleration level for two minutes under each breathing condition. At +12 G_x, the data showed that performance under conditions of positive pressure breathing of 100% oxygen was superior to normal atmospheric breathing of 100% oxygen. Subjectively, the pilots reported that positive pressure breathing of 100% oxygen was superior to the condition of normal breathing of 100% oxygen in terms of breathing ease and general comfort (Chambers, et al, 1962).

DYNAMIC FLIGHT SIMULATION AND ASTRONAUT ACCELERATION TRAINING

By using centrifuges, rocket tracks, and other acceleration devices, it is possible to produce some of the acceleration conditions of real flight. Unconstrained motion with aircraft and spacecraft involves six degrees of freedom which may be conveniently expressed in terms of six components, three of which are linear accelerations and three of which are orthogonal angular accelerations. For any given aircraft or spacecraft, some of these components are more important than others, and the ways in which they are combined determine the complexity of the pilot's acceleration environment.

The AMAL human centrifuge has been one of the primary facilities for simulating the acceleration conditions expected to be encountered in actual flight. Its history in simulation of X-15, Mercury, Dyna-Soar (X-20), Gemini, Apollo and a large number of aircraft is well known. There are many other facilities throughout the world, although none are as large nor do any other facilities have the capability for computer controlled pilot-in-the-loop operations. There are 8 human centrifuges in the United States, as shown in Table 1. There are also 7 other centrifuges in other parts of the world.

A photograph of the gondola of the AMAL human centrifuge (which is at the end of a 50-foot arm) and a Mercury astronaut, is shown in Figure 37. After the astronaut enters the centrifuge, the hatch may be closed, and the atmospheric pressure, temperature, and breathing air conditions may be regulated in order to simulate some of the other environmental conditions which may be encountered during normal launch, reentry, and emergency abort maneuvers.

In Figure 38, an astronaut in his cockpit within the AMAL human centrifuge gondola is shown. Figure 39 shows a similar view, except that the astronaut is wearing a flight suit, rather than a pressure suit, and his head is restrained firmly in his form fitted contour couch. The astronaut within the gondola of the centrifuge is provided with an instrument display panel, a control device, and other piloting equipment as required. The pilot operates his control devices in response to information presented on the instrument panel and cues which he receives during the acceleration. The analog computers are used to close the loop between the pilot, his displays, his controls, and the centrifuge accelerations. Thus, the control movements which the pilot makes are converted into electrical signals and fed into the analog computer, which continuously generates the flight problem and provides solutions which result in output signals. Some of the signal outputs are transformed by a coordinate conversion system into appropriate centrifuge control signals which regulate the power voltages to the arm and gimbal system of the gondola. Simultaneously, the other signal outputs are fed to the pilot's instruments.

Table 1

CENTRIFUGES IN THE UNITED STATES AVAILABLE FOR HUMAN TESTING IN 1964[1]

	AMAL, NADC Johnsville, Pennsylvania	AML, WPAFB Dayton, Ohio	ARC, NASA Moffett Field, Calif (5 Degrees of Motion Simulator)	Grumman Engr Co Bethpage N Y	Mayo Clinic Rochester, Minnesota	SAM, USAF Brooks AFB Texas	SAM, USN Pensacola, Florida	Univ. of Southern California Los Angeles, California
Arm Length, pilot to hub	50 ft [a,d]	*19 ft [a]	30 ft [a]	20 ft [a]	14.5 ft [b]	20 ft [a]	20 ft [a]	24 ft [b]
Main Drive Type (AC, DC or engine) Rated speed (rpm) of gondola	DC motor direct coupled 48.5 rpm *(110 rpm) [d]	*3 DC motors plus flywheel *55 rpm (approx.)	DC motor 24.3 rpm	Hydraulic system 80 rpm	AC motor 60 rpm	DC motor, hydraulic drive 40 rpm	Internal combustion engine 60 rpm	DC motor and flywheel 60 rpm
Radial g Maximum g Onset rate (g/sec) Rate of decline (g/sec)	40 *(100) [d] 10 g/sec, 1.5g to 15g 5 g/sec, 15g to 40g 10 g/sec, 15g to 1.5g 5 g/sec, 40g to 15g	*20 (85 g spike) *10-12 g/sec at 2g base *10-12 g/sec	6 2 g/sec from 2 g to 6 g 2 g/sec from 2 g to 6 g	40 1.25 g/sec 3.0 g/sec	15 3 g/sec 3 g/sec	50 1 g/sec to 10g 3 g/sec 10-50g Variable	15 1.5 g/sec 1.5 g/sec	15 5 g/sec 5 g/sec
Gondola Shape Size Gondola interchangeability Crew capacity Auxiliary cradles	Oblate spheroid *(sphere) 10 ft x 6 ft *(10 ft dia) No *(yes) 1 *(2-1) Yes	*Sphere *10 ft *Yes *1-2 *No	Cylindrical, cone-shaped ends Cyl. 5.5 ft dia., 5 ft long Cones 10" high Yes 1 (2 with severe restrictions) No	Platform -- No 1 No	Rectangular 6 x 3 x 4 ft No 2 Yes	Modified "tip tank" shape 6 ft dia., 9 ft long Yes [f] 1 No	Custom constructed Custom constructed Yes 1 No	Circular cab 6 ft dia., 8 ft high No 3 No
Payload Lb in gondola at peak g	100 lb *(1000 lb) (5000 lb) [d]	*500 lb at 20 g	500 lb	2,000 lb	500 lb	10,000 lb	450 lb	2,000 lb
Degrees of Freedom	1 *(3 with prov. for 4)	*6 (including vibration)	5	1	2	1	1	1
Gimbals	2-limited roll *(2 prov. for 3 full rotation)	*2	1	None	1	None	None	1
Mode of Control Manual Cams Punched tape Computer	Yes Yes Yes Yes	*Yes *No *Yes *Yes (digital)	Yes No No Yes	Yes No No No	Yes No No Yes	Yes No No No	Yes No No No	Yes No No No
Mode of Braking Electrical Friction	Yes Yes	*Yes *Yes	Yes Yes	No No [g]	Yes No	No Yes [g]	No Yes	No Yes
Closed Loop Operation Centrifuge Instrument panel	Yes Yes	*No *Yes	Yes Yes [e]	No Yes	Yes Yes	No No	No No	No *(planned) Yes
Gondola Environments Pressure altitude (max. ft.) Temperature range Humidity range (% R. H.) Env. control during rotation	60,000 *(100,000) *(-40 F to +160 F) ambient *(Proposed)	*60,000 *40-110 F *10-90% R. H. *Yes	ambient ventilation only ambient No	None None None No	ambient ambient ambient No	None None None No	ambient ambient ambient chamber air conditioned	None None None No
Vibration Capability Frequency range (cps) Amplitude range (inches)	*(Proposed) *(Proposed)	*1-15 cps to 9" ampl. or 15 g *±12" (Z-axis) ±3-4" (X and Y)	No No	None [e] None [e]	No No	None None	None None	Under construction Under construction
Slip Rings	75 *(104: +124 to gondola, 144 to hub)	*425	50 physiological, 150 instrumentation and project	50	60 two-lead channels	200	72	100
Visual Displays	*(Proposed)	*Yes	No	None [e]	No	None	Yes	No
Present/Future Training or Research	Basic research in physiology. Space flight simulation and astronaut training. Shoulder harness, restraint systems, anti-g suits. Controls and displays	*Tolerance and performance studies with regard to interaction of environmental variables, and hardware and testing	Basic research in physiology and psychology. Space flight simulation	Disorientation and flight simulation. Equipment testing	Cardiopulmonary effects of acceleration	25% training and indoctrination, 25% clinical evaluation, 50% human and animal experiments on tolerance, etc.	Effects of continuous slow rotation and vestibular disorientation.	Sensitivity of carotid sinus mechanism and effect of acceleration on blood lymph circulation and fluid balance in extremities. Also performance studies

* Approved or under construction.
[a] Single-ended
[b] Double-ended
[c] Regenerative
[d] 22-ft. arm (section removable)
[e] Part of payload
[f] Second gondola not available
[g] Hydraulic pressure

[1] Other facilities planned or under construction to be operational after 1964:
Ames Research Center, NASA, Moffett Field, California - Man-carrying motion generator
Manned Spacecraft Center, NASA, Houston 1, Texas
Goddard Space Flight Center, NASA, Greenbelt, Maryland
Minneapolis Honeywell Regulator Company, Minneapolis, Minnesota

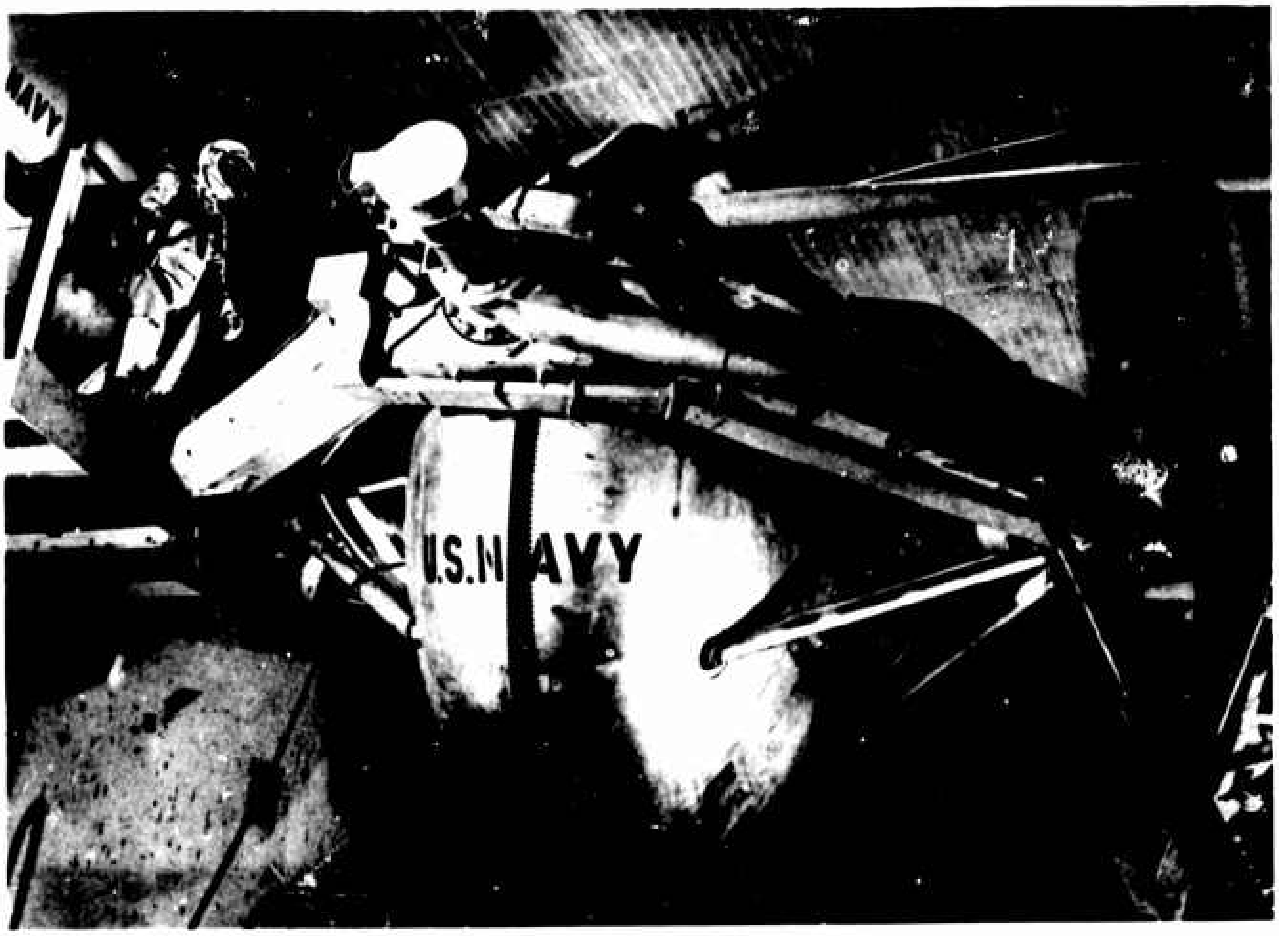


Figure 57. Pilot entering the two-gimbaled gondola at the end of the 50-foot arm of the AMAL Human Centrifuge

Figure 38. Project Mercury astronaut performing a capsule attitude control maneuver during a simulated space flight in the AMAL Human Centrifuge

Figure 39. Mercury Astronaut performing a capsule attitude control maneuver during a simulated space flight, during early centrifuge simulations of Mercury flights

The pilot-centrifuge-computer system described above consists basically of two closed-loop systems: one connecting the pilot's control responses with the driving system of the centrifuge, and the other connecting the pilot's control responses with the driving mechanisms of the indicators on the pilot's instrument panel. (Hardy, et al, 1959; Chambers and Doerfel, 1959; Chambers, 1962.)

During a typical simulation program on the AMAL centrifuge, there are from 3 to 9 duty stations at which various types of recordings are taken. These recordings include psychological performance, medical, and engineering data. Sometimes, a large analog computer system records performance error as a function of the programmed task and may, if desired, convert the analog scores to integrated error scores or to digital readouts on IBM cards. Another computer system computes means and variability for each run as the run proceeds, thereby providing detailed in-line scoring as each run progresses. In addition, there are several additional data processing systems available for special purpose analysis such as a 14-channel magnetic tape recorder. On-line data recording and data processing is provided by feeding the responses through a small analog computer system which simultaneously yields individual means and standard deviations of the subject's performance on several task components.

If programmed appropriately, the human centrifuge may be used as a dynamic simulation device in which physiology and performance of pilots, and the behavior and effectiveness of cockpit instruments, may be studied and evaluated. If programmed to simulate specific types of aerospace vehicles during definite portions of flight maneuvers, the human centrifuge may serve as a very useful tool for identifying and investigating some of the human factors problems associated with a wide variety of the acceleration aspects of flight. The effects of acceleration on pilot physiology, pilot performance and pilot ability to use specific controls, displays, and escape equipment may be investigated. In addition, if the centrifuge is instrumented with appropriate environmental conditions such as atmospheric pressure, pressure suit, oxygen and other gaseous conditions, and computer control of the behavior of both centrifuge and the panel instrument, the centrifuge serves as a very useful tool for studying the effects of combinations of conditions which a pilot may expect to encounter during any given particular acceleration phase of his flight. Consequently, the centrifuge may serve as a very effective tool for studying the integrated performance of the pilot and many selected aspects of cockpit, displays, controls, and environmental conditions. The interaction effects may serve as convenient indications of complete man-machine systems performance.

The human centrifuge has been found to be a very useful device for astronaut training. Since 1958 it has been one of the major training devices for preparing the Mercury astronauts for the acceleration phases of their suborbital and orbital space flights. The active Mercury-type instrument panel, Mercury-type side-arm controller, complete environmental controller, complete environmental control system, and remotely-controlled centrifuge drive system permitted extensive training on a wide

variety of piloting tasks and emergency conditions during exposure to the various acceleration profiles for the Redstone and for the Atlas Mercury flight maneuvers. The associated telepanel indicator lights, which were presented at specific time intervals, constituted additional training. An example of this training condition is presented in Figure 40, in which the acceleration profile and its associated events are summarized.

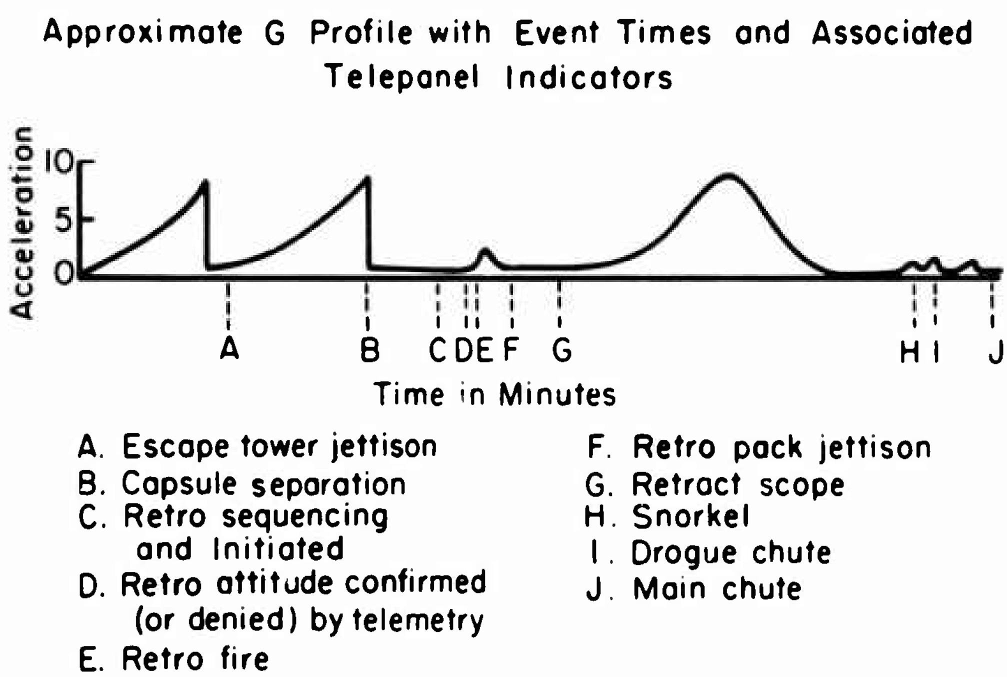


Figure 40. Approximate G profile with event times and associated telepanel indicators used in centrifuge simulations and astronaut training in support of Project Mercury

During the five major acceleration training programs, and the additional refresher training programs that were conducted for the Mercury astronauts, the astronauts received practice in straining in order to maintain good vision and physiological functioning under high G loads, and in developing breathing and speaking techniques during high G launch, reentry, and abort stress. Experience in tumbling and oscillations during relatively high G exposures also was provided. The astronauts were given extensive practice in controlling their simulated vehicles during reentry and other phases of their simulated flights. They became skilled in the operation of their environmental control systems and capsule communication procedures during acceleration

exposure. Simultaneously, extensive physiological monitoring and performance provided continuous information on astronaut endurance and piloting skill.

Complete mission simulations were presented during which early morning suiting, psychiatric testing, waiting in the gondola, launch, orbit, reentry, recovery, escape, post-flight testing, and debriefing were provided on a real-time basis. This type of simulation presented physiological and psychological conditioning and man-machine evaluations along real-time scale profiles. An additional advantage of this type of training was that the astronauts were able to experience the many subtle and elusive interactions which occur between the physiological, psychological and engineering stress variables. Evaluations of the AMAL centrifuge as a Mercury astronaut acceleration training device have been very favorable (Slayton, 1961; Glenn, 1961, 1962; Shepard, 1961; Grissom, 1961; Voas, 1961a, 1961b; Carpenter, 1962; Chambers and Fried, 1963).

Similar procedures have been used in training test pilots and astronauts in support of Project Gemini, Project Apollo and Project X-20 (Dyna-Soar). Figure 41 shows a typical installation in the centrifuge for the Project Gemini simulation. In Figure 42, a typical Gemini profile and some associated physiological effects of this profile as measured in the centrifuge are presented. An example of the physiological data which were obtained in support of problems expected on high accelerations typical of Apollo maneuvers are presented in Figure 43.

A summary of the centrifuge programs which have been conducted on the AMAL human centrifuge in support of National Space projects since the completion of Project Mercury is presented in Table 2. The table suggests that the techniques of centrifuge simulation of space flight have been extensively used in order to study the psychophysiological effects of acceleration, in training astronauts and test pilots, and to obtain engineering and instrumentation test data. Acceleration training results in physiological adaptation and conditioning as well as in learning to make performance compensations for the acceleration disturbances. The pilot improves his piloting performance by: (a) accommodating to the sensations induced by acceleration, (b) learning to resist the effects of acceleration through the use of proper straining and breathing techniques, (c) learning the task in the context of changed muscular and sensory capacities induced by acceleration, (d) learning to execute the physiological and performance aspects of the task simultaneously, (e) learning to concentrate on the task despite pain and discomfort resulting from the acceleration, and (f) building his confidence.

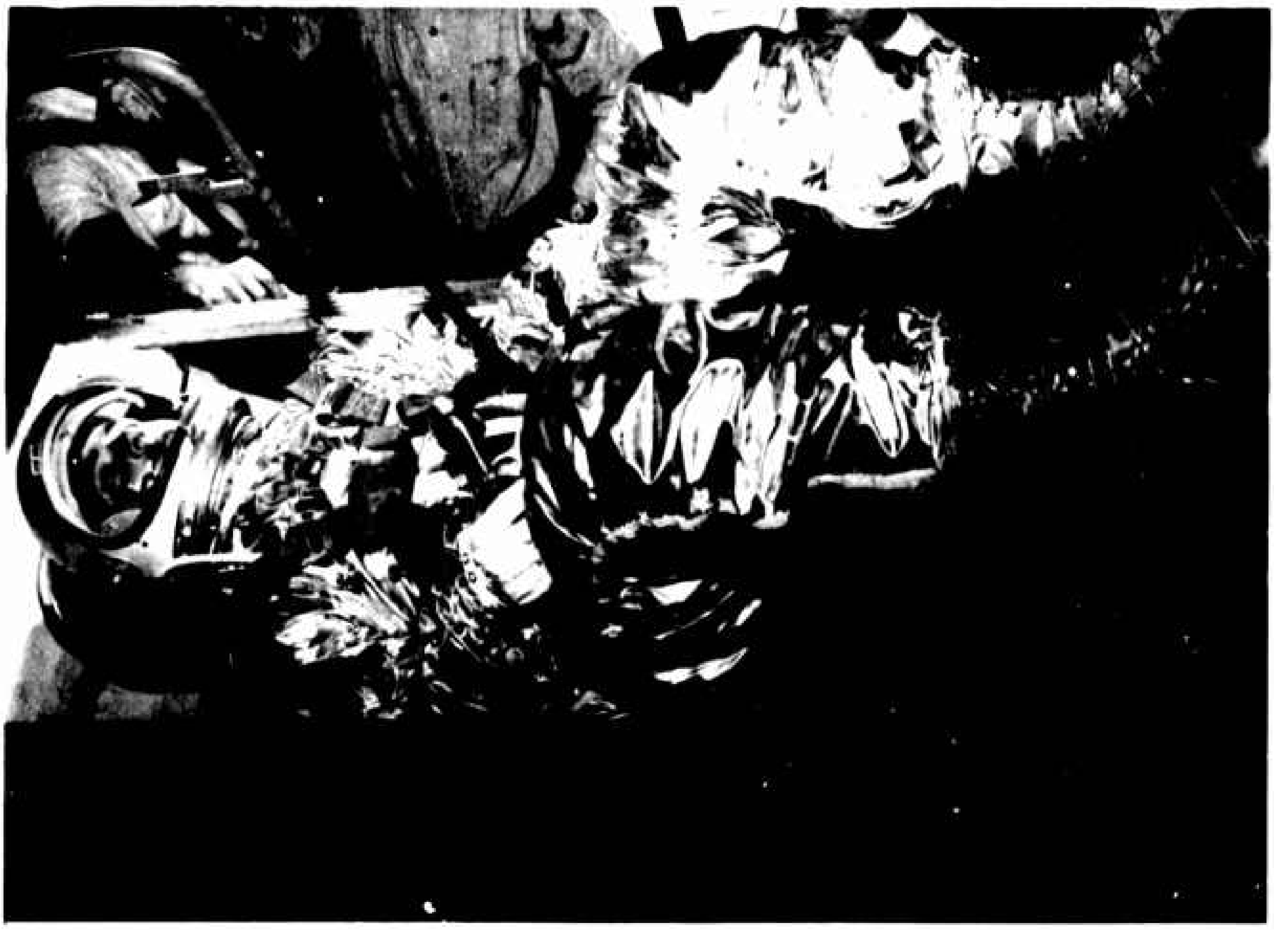


Figure 41. Cockpit installation used for early training of Gemini astronauts on the AMAL Human Centrifuge and for simulating manned Gemini flight acceleration profiles.

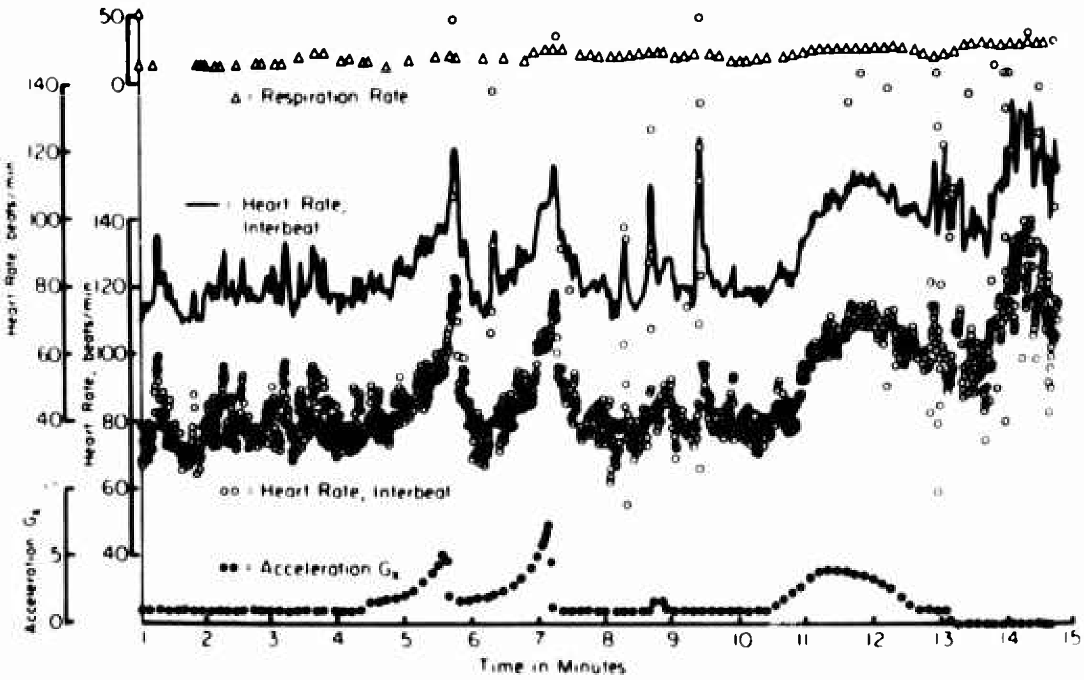


Figure 42. Example of physiological responses to a centrifuge simulation of a Gemini acceleration profile. (The acceleration profile and the resulting electrocardiographic and respiratory data were obtained from the AMAL Human Centrifuge in support of Project Gemini)

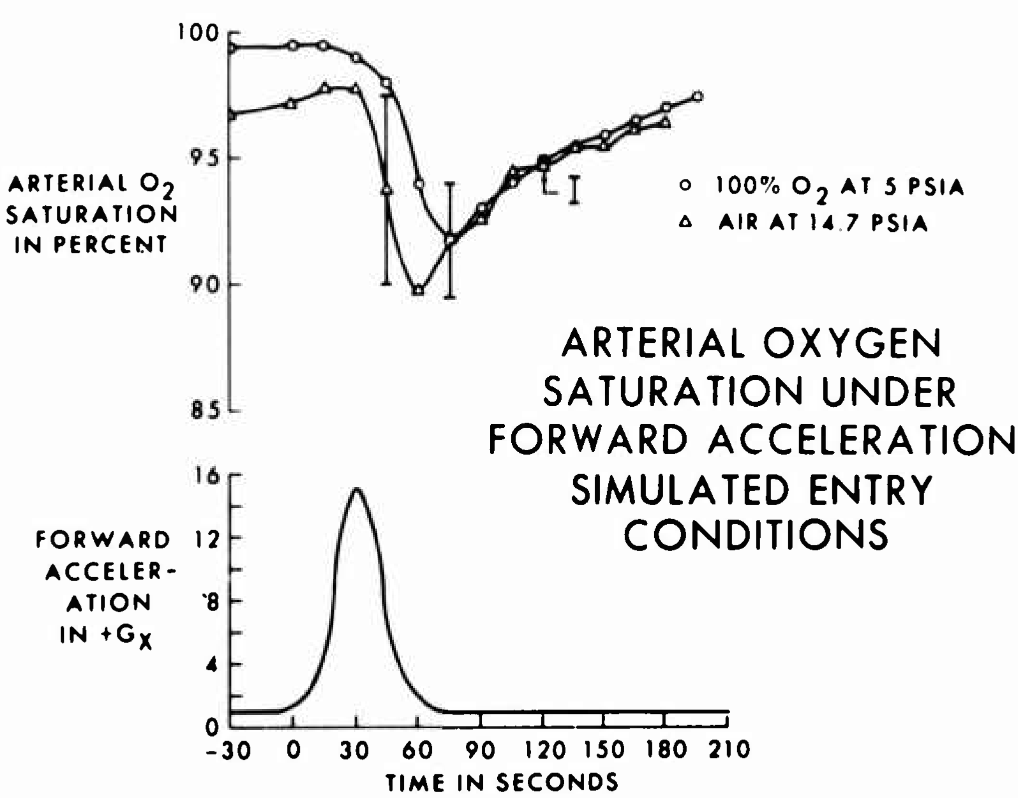


Figure 43. Arterial oxygen saturation under G_X entry conditions simulated on the AMAL Human Centrifuge

Table 2

Summary of Centrifuge Programs Conducted on the AMAL Centrifuge in Support

of National Space Projects Since Project Mercury

Centrifuge Program	Dyna-Soar	Military Astronaut Training Program II	Military Astronaut Training Program III	Gemini Phase I	NASA Basic Physiological Study	Military Astronaut Training Program IV	Apollo Phase I
Centrifuge Operational Dates	11 June 7 Sept'62	1 Dec 19 Dec'62	26 Feb 6 Mar'63	29 June 1 Aug'63	1 Aug 2 Oct'63	26 Aug 30 Sept 30 Aug 4 Oct	23 Oct 6 Dec'63
Coordinating Agency	NASA SPO	EAFB HSTPS	EAFB HSTPS	NASA MSC	MSC, Crew Systems Div.	EAFB HSTPS	NASA APO-MSC
Unmanned Dynamic Runs	47	193	91	54		10	54
Manned Static Astro. & Pilot	202	31	31	121	94	60	115
Manned Dynamic Astro. & Pilot	141	102	137	162	219	77	169
Total Dyn.&Stat.	343	133	168	276	313	137	284
Number of Astro. & Pilot	11	12	12	16	27	16	6
Manned Static Other	250 Approx.	32	0	17	0	0	20
Manned Dynamic Other	45	78	5	19	0	0	46
Total Dynamic & Stat.	45	110	5	36	0	0	66
Number of Other	4	10	1	6	0	0	7
Total All Subj.	15	22	13	22	27	16	13
All Dyn. - Stat. Runs	638 Approx.	243	173	312	313	137	350

CONCLUSIONS

Nineteen general conclusions may be reported regarding the psychophysiological aspects of acceleration stress. These may be stated as follows:

1. Physiological tolerance. Physiological tolerance, or the ability to withstand physiologically any acceleration stress, is a function of many variables: rate of G-onset; magnitude of peak G; duration at peak G; total G time; direction of primary G vector with respect to the body; and pattern complexity.

2. Performance tolerance. In addition to physiological tolerance limits which define the end points for reliable functioning of any particular physiological system during exposure to acceleration stress, there also are performance tolerance limits which define the end points for reliable functioning of any particular performance ability system under these same conditions of acceleration. The physiological and performance tolerance may be functionally related, but need not be the same, since both are dependent upon the criteria which are accepted.

3. Relationship between performance and physiological tolerances. Physiological tolerance limits define certain performance tolerance boundaries. However, within these boundaries, the prediction of performance tolerances from physiological tolerances is extremely unreliable.

4. G-protection. The type of G-protection used has a very important influence on the pilot's ability to tolerate acceleration, perform tasks, and maintain proficiency during acceleration stress.

5. Direction of primary G vector. For an acceleration of given rate of onset and magnitude, physiological tolerance is highest for G_X, next for $-G_X$, next for G_Z, and lowest for $-G_Z$ directions of force.

6. Visual Decrement. Acceleration significantly influences the ability to see. During the occurrence of all types of high acceleration, the human pilot experiences visual disturbances. These disturbances result from shifts in the availability of arterial blood to the retina; mechanical pressure on the eyes and associated structures; distortions of the eye anatomy; and accumulation of tears.

7. Individual Differences. Major individual differences exist among human subjects in their ability to sustain acceleration stress at high G.

8. Acceleration Training and Practice Effects. Major increments occur as a function of practice. Practice results in physiological adaptation and conditioning, as well as learning to make compensations for the acceleration disturbances. Ability to perform improves by (a) accommodating to the sensations induced by G, (b) learning to resist

the effects of G through proper straining and breathing techniques, (c) learning the task in the context of changed muscular and sensory capacities induced by the acceleration, (d) learning to execute the physiological and performance aspects simultaneously, and (e) building confidence in one's self.

9. Illusions of motion and position. Certain types of acceleration exposures produce illusions, or false perceptions, of one's position and motion.

10. G-Perception. The human can sense very slight changes in angular acceleration and also in linear acceleration.

11. Control Devices. The nature of the control device which is used in performing a task under G has a significant effect upon performance.

12. Feedback Sensitivity. Acceleration impairs the ability of the pilot to sense changes in control characteristics which may occur as a function of specific acceleration vectors. There may be direct results of the acceleration forces on the receptors; there may be an effect on the central or autonomic nervous system; or there may be an effect on circulatory and other physiological systems which indirectly affect the ability of the subject to sense changes in his hand and/or fingers.

13. Task difficulty. Changes in task characteristics which have little effect upon static performance may seriously impair performance under high G.

14. Higher Mental Functions. Intellectual skills, pilot concentration, time judgment, time perception, prediction, and immediate memory, are influenced by G.

15. Emotional Processes, Fear, and Anxiety. Anticipation of the effects of acceleration may produce emotional reactions, fear, and anxiety, which are sometimes greater than the direct effects of acceleration themselves.

16. Characteristics of Performance Decrement. During the hundreds of acceleration tests which have been conducted on astronauts, test pilots, and volunteers, rather specific characteristics of piloting performance impairment have been observed under high acceleration conditions.

17. Effects of Combined Stresses. Significant effects of acceleration occur as a function of combined stresses, even though, taken independently, each stress may not produce the effect.

18. Effects of changing G Fields. Ability to tolerate any given acceleration stress exposure is readily influenced by the acceleration environment in which the subject was exposed immediately prior to the

exposure. High G is more difficult to tolerate if the subject was weightless just prior to exposure than if he was at 1 G prior to the exposure. On the other hand, immediate prior exposure to high G may temporarily reduce acceleration tolerance if adequate recovery time has not been provided.

19. Pharmacological Effects. Certain types of pharmacological agents are believed to alter acceleration tolerance, as well as the ability of the pilot to perform complex tasks during exposure to acceleration stress.

NOTE All figures presented in this chapter are official photographs of the U. S. Navy. Release for publication in this document by permission of the Chief of Naval Operations.

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CHAPTER 9

SAUL B. SELLS
NURHAN FINDIKYAN

PSYCHOPHYSIOLOGICAL PARAMETERS OF SKILL MAINTENANCE

Maintenance of skilled performance in the face of extreme environmental conditions, threatening situations, and fluctuations in individual states is a major military and aerospace problem. Although scientists and engineers have become more sophisticated about stress-performance impairment questions than during the enthusiastic years following World War II, there are still strong pressures to provide univariate solutions to what is fundamentally a complex multivariate problem.

Sophistication is reflected chiefly in new knowledge concerning the neuropsychology of arousal, the recognition of qualitative differences among various "stress" mechanisms, and the refinement of criteria. Military and aerospace scientists have found it necessary to distinguish between discomfort, skill impairment, physiological impairment, and survival effects of various states and environmental stimuli. In the analysis of these problems, exposure duration is recognized as a significant variable. The fact that for almost every stimulus variable there is a continuum from activation to response facilitation to impairment to disorganization is recognized, making the study of stress a quantitative as well as qualitative problem.

Research progress has been and probably will continue to be hindered by ethical restraints and the sheer complexity of the problem. Investigators and their sources of financial support are constrained from exposing valuable human subjects to realistic dangers in the search for new knowledge, despite the ultimate savings in human lives that might result. Also, they are constrained from risking impairment of important programs and equipment for research support. As a result, scientifically excellent research has frequently been confined to the use of "available" subjects and restricted stimulus conditions to a degree that renders results vitually sterile, insofar as generalization to realistc situations is concerned.

Complexity refers to the multifaceted nature of the problem. In the study of skill maintenance and impairment, it is important not only to understand the processes which maintain and impair, but to specify the relevant associated variables. These include, to mention only some of the more prominent variables, (1) individual differences in experience, training, prior exposure, status and relation to the task, motivation, and psychological and physiological resources, (2) task characteristics, including difficulty, importance to the operator(s) at the time,

and complexity in relation to other on-going activities, and (3) the full range of other environmental factors present in the phenomenal situation (stress interaction), including other persons directly and indirectly involved, physical parameters, and a host of social, cultural, and group interaction variables.

The review of the literature on the effects and mitigation of detrimental values of temperature, atmospheric composition and pressures, noise, radiation, isolation, gravitational force (including weightlessness), sleep loss, nutritional intake, and others discussed in this report, reveals primarily a frustrating hodge-podge of facts that are difficult to interpret without a systematic frame of reference. Laboratory studies have been generally rewarding in specifying relevant information about subjects, task, and environmental conditions, although they often have been hampered by lack of realism in choice of subjects, motivation of subjects, task conditions, and range of stress stimuli tested. The scientific advantages of isolation of factors in the laboratory do not, however, offset the need for extension of research to more complex conditions from which generalization to practical problems must be made. Field observations have frequently been quantified and based on highly realistic exposure conditions, but the lack of control and difficulty of specification of subjects, task, and environmental frame of reference have created equally serious interpretation problems.

Despite the difficulties mentioned, the published literature provides a basis for an extensive list of generalizations concerning the direct and indirect effects of organism-environment interaction conditions encountered in both conventional and new military and aerospace activities that have been found threatening to the maintenance of skilled performance. While the emphasis in this report is on ways and means of mitigation of performance decrement, identification of the factors involved in production of decrement and of human tolerance parameters is a necessary supplementary task.

DIMENSIONS OF THE PROBLEM

FACTORS PRODUCING PERFORMANCE DECREMENT

A significant trend in military and aerospace programs has been toward comparatively small, detached organizations operating in relative isolation, frequently in exceptional environmental circumstances, and under unusual task conditions. Even conventional forces have become more mobile and face new requirements of adaptability and skilled performance under more diverse conditions than ever before. These problems have gone beyond the testing of human endurance to the extreme conditions encountered on the surface of the earth, to environmental

parameters to which the species homo sapiens is not developmentally adapted and for which he must make adequate provision not only to survive but also to live comfortably and perform effectively.

The conditions of effective performance are complex. They involve characteristics of the individual with respect to health, fitness, aptitude, training, adaptation, conditioning, and motivation for the task and its environs. On the other side, they involve the demands of the task and the environs in which it must be performed. Extreme deviation in any parameter or combinations of less extreme variation of many relevant parameters could result in the degradation of performance to a point that might impair the accomplishment of a mission. Responsibility for maintenance of effective performance is therefore widely distributed and in the end demands cooperation of scientists, physicians, nutritionists, engineers and manufacturers, as well as military commanders.

The parameters of skilled performance included in this review fall logically into four overlapping categories, distinguished by their sources and mechanisms, although their interactions are also of major interest. These are (1) components of the physical environment, including extreme temperatures, atmospheric pressures, mixtures, and contaminants, noise and vibration, ionizing radiations, and gravity; (2) social-environmental factors resulting from task demands, compatibility, orientation, and location, such as isolation, confinement, high task load, and sleep deprivation; (3) psychophysiological aspects of individual behavior, such as fatigue, diurnal and other cycles, and nutrition; and (4) reactions to severe threat. The emphasis here is on individual behavior. Social and group behavior under stress constitute a major related problem which is not included in this report.

The specific mechanisms of these "stressors" can in most cases be reported, together with effects which have been observed or tested under particular conditions and with particular criteria. A major advance in the study of "stresses" in recent years is the recognition of their specificity, (See Broadbent, 1963; Lazarus, 1964; Korchin, 1962; Schaefer, 1962; and others) in contrast to the earlier emphasis on generality and nonspecificity (Selye 1956 and Miller 1960).

The action of these mechanisms is dependent on the simultaneous occurrence of other responses with which their effects may combine (e.g. cold and fear) or which may partially cancel each other (e.g. noise-overarousing, and sleep loss-underarousing). The motivation of the individual, the support or interference with his motivation received from group sources, his level of physiological adaptation, conditioning and prior experience in the situation, his expectations and confidence in his own reactions, his competency, and in his equipment, colleagues, and superiors have significant influence on stress tolerance and performance. Different mechanisms and combinations of them also may be expected to affect different types of tasks differentially.

INTERACTIONS

One reason why well-known "stressors," such as temperature of 130 F, do not always influence behavior as dramatically in the laboratory as they do in the field is that in real-life field situations they do not usually occur in the controlled isolation, painstakingly achieved in the laboratory. Although heat is mentioned as the central factor in tropical climes, the actual field environment of the foot soldier in the tropics also includes, in complex profusion, dampness, humidity, insects, jungle hazards, heavy packs, clothing, strenuous work, and perhaps other sources of annoyance, fatigue, and fear.

While it is scientifically important to understand the specific mechanisms in order better to understand their interactions with other mechanisms of reaction in complex environmental situations, the ultimate goal of scientific inquiry in support of military effectiveness must be the understanding of the complex reactions to known complex situations. So far as possible, such interactions are reported in the discussion below, but it must be acknowledged that present information of this kind is quite inadequate. Although many offsetting relations have been found, as in the case of arousing noise offsetting the underarousal of sleep loss, most stress interactions appear to have both synergistic effects and secondary overcompensating effects which are often magnified greatly in intensity.

It is, of course, necessary to understand that maintenance of proficiency under stress is a goal opposed to the adaptive functions of all physiological and psychological defenses, which may urge the individual to behavior changes involving control of impulse, abandonment of the task, or at least degradation of performance.

TOLERANCE LIMITS

The limits of human tolerance to various stresses are inadequately known and probably will never be finally determined. Until individual differences are more extensively explored and the combined effects of dedicated motivation, physiological adaptation, and accustomization are fully exploited, the extension of human tolerance to environmental stress is really a relative question with reference to the possible end points. The importance of this point is emphasized, first by the differences between average American personnel and natives of remote areas in adaptation to cold, heat, drought, altitude, and isolation, and second, by the development of "artificial" methods of adaptation, in recent years, to extreme temperatures and to altitude.

It is probably true that the austerity and dislocations of personal lives required for these purposes are extremely unattractive to Americans, in the face of the progress achieved by engineers in overcoming almost all obstacles of the environment that they have attacked to date. In

this cultural setting it is perhaps pragmatically necessary to advise the engineers of the levels of the stress variables beyond which protection, support, comfort, and facilitation of human effort must be provided, to insure mission success.

Such pragmatic levels can be reported for many variables and situations on the basis of existing data. However, this information is limited and often inaccurate in several respects. One type of error is that tolerance, measured in terms of physiological parameters, may be unrelated to performance of various skilled tasks. For example, it has been found that massive physiological damage can be endured, in some cases, without impairment of some performances. The second type of error is that tolerance limits based on "average" individuals, without reference to the range of individual differences, may be seriously distorted.

Finally, it must be emphasized that tolerance limits for any variable, taken singly, cannot be unequivocally accepted for that variable in complex situations. In most cases, the effects of additional stresses are in the direction of lowering the critical points.

APPROACHES TO PERFORMANCE MAINTENANCE

Maintenance of skilled performance in stressful situations is a complex task with many facets, each of which calls on certain scientific disciplines and technologies. Unfortunately, the various approaches discussed below frequently have proprietary status among their adherents and must often compete for budgetary support. As a result the concept has developed in certain quarters that these are to some extent alternative approaches.

Nothing could be farther from the truth. Indeed, the measures discussed in this section: selection, adaptation, training and conditioning, nutrition and psychopharmacology, protective equipment, environmental engineering, task systems engineering, psychophysiological monitoring, and organizational management, are interdependent, but largely discrete. On one hand they are concerned with the extension of human tolerance and human capacity as far as possible, and on the other, with "making up the difference" by providing optimal environmental support and facilitation. Mitigation of stress is one part of the task; the second is a positive approach to the maximizing of performance effectiveness.

The following discussion of the general features and potential contributions of these measures merits consideration for two strategic reasons. First, review of recent literature reflects only a piecemeal, rather than a systematic approach, in most cases. And second, the optimal solution of the general problem requires the systematic, coordinated exploitation of all available measures. Although budgetary exigencies may impose restraints on implementation in specific cases, a realistic view of the goal requires that the full range of possible approaches be included in the analysis.

Selection. The existence of individual differences in tolerance of any stressor is an invitation to investigate the feasibility of selection. However, the opportunities afforded by this approach have virtually been ignored. For example, in 1953, McCleary, in an experimental study of manual performance at low ambient temperatures (down to -40° F), found that individual differences in loss of digital temperature among his volunteer basic airman subjects permitted the computation of a sensitivity index of skin temperature loss over exposure time which discriminated significantly among subjects on performance of the task in the cold. Yet, to our knowledge, no follow-up of this work has occurred. Individual differences have been found in tolerance of heat stress, acceleration, altitude, weightlessness, sensory deprivation and other stresses. While it is possible that selection on other major factors may require a higher priority than some particular stress tolerance measure in particular cases, the development of batteries of specifically focused stress tolerance tests for selection should be encouraged in an overall program of performance maintenance.

Adaptation. The full exploitation of physiological adaptation and immunization processes to increase tolerance to environmental stresses would be a giant step in any systematic program of maintenance of skilled performance in many critical situations. When one observes the tolerance of extreme cold by naked Australian aborigines and by strategically clad Eskimos, the altitude tolerance of Andean natives who work effectively at altitudes around 14,000 feet, and the heat tolerance of desert peoples over the earth, the value of effective programs for adaptation is emphasized. This conclusion is strengthened by work such as that of Davis (1961), who has developed "artificial" methods of cold adaptation which are faster and retained longer than natural acclimatization and are believed to increase resistance to cold injury. Other work has demonstrated the feasibility of adaptation to heat (although not to dehydration), to altitudes of at least 14,000 feet and to acceleration stresses. The possibility of adaptation, to some degree, to ionizing radiation, CO_2, different diurnal cycles, and other critical conditions deserves continued study.

Comprehensive training and conditioning programs. A distinction must be made between physiological adaptation, under the general control of the nervous and endocrine systems and involving biochemical processes of cellular change, and other related adaptive processes. Among the naturally adapted peoples of various regions cited, natural selection over extremely long time periods has unquestionably been an additional important factor. However, the contribution of complex habituation processes and ecologically appropriate behavior patterns of dress, diet, work-rest cycles, shelter, and activity must be emphasized as being of special interest in the present context.

Physical and psychological conditioning and accustomization to the actual environmental conditions in which critical performance is to occur enable the individual to accommodate his performance to the situation and to develop insight and accurate expectations concerning the

task requirements as well as his own reactions, thus eliminating uncertainty and increasing confidence in his ability to perform under the required conditions.

An experimental illustration of accustomization is seen in the study of Clark and Jones (1962), who gave subjects varied thermal experience (warm and cold hands) during three weeks of training on a standard manual task. They found (a) that one day of cold-hand training significantly reduced the size of manual decrement usually encountered with cold exposure, although continued cold experience did not; (b) that skill-level on the task *per se* did not interact with cold-induced performance decrement; and (c) that the thermal conditions associated with task performance appeared to become part of the stimulus complex eliciting complex correct manual responses when these were maintained over a large number of trials. In other words, the subjects learned not merely to perform the task, but to perform in particular ways with warm and cold hands.

The implications for achieving realism in training programs involving unusual environments cannot be underestimated, as Torrance (Undated), Edgerton (1953), and others have pointed out.

Perhaps the outstanding example of the exploitation of this approach, including the extensive use of environmental and mission performance simulators, has been the NASA Mercury Program in which the complex movements, thrusts, atmospheres, work-space and personal equipment restrictions, and other significant aspects of the mission were effectively simulated in real-time performance on the ground before the first shot. The reports of the astronauts (Carpenter, 1962; Glenn, 1962; Schirra, 1962) in debriefing give ample testimony to the contribution of these preparations to the success of this program.

Accustomization includes so many facets of performance situations that a complete inventory would be out of place in this discussion. Nevertheless, the following representative list may contribute to a broad appreciation of the magnitude of the problem. In addition to the parameters of atmosphere, light, effective temperature, gravity, noise, vibration, and the like, other important factors to which accustomization may be desirable include work-rest cycles, body positions and restraints, special diets, water supply, provisions for personal hygiene, accommodations for work, recreation, sleep and rest, communication opportunities and facilities, special restrictions and deprivations (smoking, for example), problems related to personal equipment, and emergency procedures.

Preconditioning may include physical conditioning, use of special diets to control body wastes, isolation to avoid infection and contaminants, stress indoctrination, and information on matters of relevance to the total task.

Nutrition and psychopharmacology. Nutrition involves at least three important aspects: supply of caloric requirements, provision of dietary component requirements, and subjective satisfactions. Research on special diets for cold, hot, and other stressful environments has demonstrated (a) the critical importance of adequate caloric intake for effective performance and (b) the secondary psychological significance of food.

Seaton's (1962) study of caloric intake of three small (six-man) groups on the Greenland Ice Cap, in which caloric reduction (to 2400 cal./day) resulted in impaired communication within groups, hostility, increased fantasy and sleeping, demonstrates the secondary effects of inadequate dietary support, over and above task performance.

Food and water requirements are related to temperature, work, and duration of the activity and may impose logistic problems when quantities to be transported or otherwise supplied are large. In situations involving long periods of stress and isolation, problems of boredom and food idiosyncracies challenge the nutritionist to provide palatable meals within the logistic constraints imposed. Food preservation, water purification, and taste and appearance problems may also increase in importance with time, although much remains to be learned about changes in taste, desire for food, and related problems in long-confinement situations.

The use of drugs to sustain performance is another vast field (Uhr and Miller, 1960) which can be commented on only briefly here. A wide variety of drugs has been studied with respect to properties which sustain vigilance, defer fatigue, tranquilize, prevent and induce sleep, prevent motion-sickness, and exercise other effects on behavior and subjective states.

Because of the possibilities of deleterious side-effects and individual differences in effective dosages and effects, physicians (e.g. flight surgeons) have been conservative in prescribing drugs for pilots and other operators in critical situations. However, psychopharmacology must be recognized as a significant approach to maintenance of skilled performance under stress. In cases where small numbers of individuals are involved in highly demanding performances, drug administration could be individually scheduled.

Individual protective equipment and environmental engineering. The vision of "shirt sleeves" space missions, in which engineered compensations for the significant stresses are "built'in" features of the capsule is far from idle, although still some years in the future. However, even when engineered microenvironments, providing adequate life support, comfort, and work facilitating features, become available for space missions, remote observation units, long-range submarines, and other outposts in unnatural environments, there will still be requirements, in space as well as on earth, for the protection of men in situations outside of the sheltered areas.

Problems of design, requirements for and development of protective capsules, life support systems, personal protective equipment and provisions for habitability, sanitation, food preparation, waste disposal, regeneration of oxygen, food, and water, pressurization, and recreation are well known, widely appreciated, and relatively well supported with research and development funds. Although many of them are still unsolved, progress in this area has been impressive and prospects are bright. Environmental protection, life support, and habitability engineering may not assure the maintenance of skilled performance, but will greatly enhance the effectiveness of the other measures toward this end.

Task systems engineering. This category includes most of the areas usually covered by engineering psychologists and human factors engineers whose goals are both to adapt the system maximally to the facilitation of human performance and to effect an optimal division of labor between man and machine components. Additionally, in multi-operator systems it involves the optimization of interactions among operators for maximum system effectiveness.

The principal features of these activities involve (a) equipment design and positioning, for instruments and displays, controls, communications facilities, work space and supporting equipment; (b) systems engineering, with respect to job definition and assignment of tasks to operators to effect optimal load balancing, autonomy, and homogeneity of function, scheduling of shifts and work-rest intervals, pacing of tasks, use of task-supporting aids (computers, calculators, slide-rules), specification of communications channels and procedures, knowledge-of-results feedback and other task-relevant information; and (c) other provisions for equipment maintenance, redundancy, maintenance of vigilance, mitigation of fatigue and boredom, and maximizing reliability of performance.

Unfortunately the contributions of human factors and engineering psychology and related disciplines have had relatively less impact in certain critical areas, such as aerospace engineering, than those of life support and environmental protection, although this is not generally true. The systematic exploitation of these disciplines is one of the greatest resources for the general program of maintaining skilled performance.

Psychophysiological monitoring. In sustained performance of unaccustomed duration and under certain conditions, such as sleep deprivation, fatigue, and hypoxia, self control and performance may be disturbed insidiously and without insight on the part of the operator. In such circumstances psychophysiological monitoring and warning systems may be a significant strategy to protect lives as well as to sustain performance. There are different levels at which performance decrement can be measured or anticipated. The most effective warning system would provide the earliest possible warning. The complex interaction of muscles, nerves, glands and other systems involved in performance requires much further clarification.

The critical importance of monitoring and effective warning was illustrated in Simons' (1958) Man-High balloon ascent, in which he was advised by a monitor on the ground to breathe 100% oxygen. This message, based on a telemetered indication of his respiratory functioning, is credited with saving Simons' life as well as the success of the mission.

Some degree of monitoring of physiological function and performance was achieved in the Mercury program. Voice communications and continuous telemetry of several physiological functions were received by ground stations throughout each mission, the latter displayed on cathode ray tubes and interpreted in real time by medical monitoring teams specially trained for the program.

While these data provided valuable ground and on-board feedback concerning the astronaut's continued health and alertness, they could be improved in at least three respects: (1) Categorical, quantitative information would be more accurate, whenever feasible, than analog data requiring clinical interpretation; (2) Predictive information, implying the analysis of developing trends, and particularly using changes in physiological function as precursors of performance decrement, would be an improvement over the present basis of monitoring, which is virtually "after the fact;" and (3) Information concerning subjective states (e.g. alertness, vigilance, composure), as well as physiological function, is needed.

Improvements in monitoring technique require further creative research, as the present state of knowledge limits the applications that can be made. An interesting illustration of such an attempt is the approach investigated by Sheer and his students at Houston, (Frazier, 1964), employing operant conditioning techniques as a basis for establishing critical responses to stress.

Organizational management. The general approach implied here involves consideration of the skilled operator as an individual person in addition to his role as a link in a complex system. It is well known that motivation accounts for a substantial part of the variance in stress tolerance of almost every stressor known, that however motivation may be characterized, it helps offset fatigue, lengthens endurance, reduces errors, and counteracts most forces that tend to degrade effective performance.

Rather than relegate this important problem to the level of exhortation or naive use of incentives, major attention must be focused on the social situation and factors which have been found to motivate workers in industrial and military situations (Likert, 1961; Herzberg, et al, 1959; Myers, 1964; Sells, 1962, 1964), which are clustered in the work organization. It is, of course, recognized that additional influence arises from factors in the general world situation, personal life situation, and the like, but except to the extent that these can be accounted for in selection and through organizational measures, they are beyond the control of the types of programs under discussion here.

The work organization provides the social environment in which a man's needs for economic and social security, status, and acceptance, and his opportunities for growth, recognition, responsibility, and achievement must be satisfied if he is to commit himself to the performance of his mission with the same zeal that he displayed on his college football team. The challenge here is to organizational management and the military command structure to utilize the principles and methods of organizational structure, supervision, reward, and management of human interaction toward the end of optimally superordinating the goals of individual participants with those of the organization.

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PART IV

ENVIRONMENTAL AND ADJUSTMENT FACTORS INFLUENCING INDIVIDUAL PERFORMANCE

INTRODUCTION TO PART IV

The discussion of environmental military medicine, including both the effects of extreme climate and the military stresses of noise, isolation, and danger, was arranged by Dr. E. Ralph Dusek, U. S. Army Research Institute of Environmental Medicine, Natick, Massachusetts. Chapter 10 was prepared by Dr. Dusek and Dr. R. Ernest Clark, also of Natick.

The writers detail the current state of knowledge about specific and measured effects on the individual of heat, cold, and altitude, and of protective equipment and the restrictions it imposes on movement, vision, and audition. They note the paucity of solid information relevant to the military effectiveness of such equipment and suggest specific problems needing research answers.

Chapter 11, on adjustment to military stress, deals with recent efforts to predict performance under stress on the basis of personality-related information. Dr. Bernard J. Fine cites studies of physiological--including biochemical--indices of behavior under anxiety-inducing conditions as the beginnings of our interdisciplinary approach. Dr. Fine is also at the U. S. Army Research Institute of Environmental Medicine.

CHAPTER 10

R. ERNEST CLARK
E. RALPH DUSEK

EFFECTS OF CLIMATE, FOOD, CLOTHING AND PROTECTIVE DEVICES ON SOLDIER PERFORMANCE

The increased accessibility and political or strategic importance of tropic, arctic, and mountainous areas of the world has resulted in a substantial increase in national defense emphasis on research in military environmental medicine. International responsibilities of the nation require that U. S. military forces be capable of successful combat on the side of or against troops indigenous to areas of extreme climate or altitude. We must, therefore, learn how to acclimatize men artifically, how to select troops who would be minimally affected by the hazards of extreme environments, how to prepare them through psychological training, exercise and proper foods, how to protect them with drugs and with clothing and equipment. And, to the extent that we fail in this protection, we must determine the best clinical management of casualties.

While research on this collection of problems is clearly multidisciplinary, the role of the behavioral sciences is gradually becoming one of leadership because of the practical need to integrate man as a system and as an operator in a complex military world. Environmental protection for the combat arms does not refer simply to the preservation of men as biological organisms, but also to the maintenance or extension of their military competence. Survival has become as obviously insufficient a goal of protection as it is clearly a necessary one. It is military competence that we must ultimately describe and preserve. Thus, organismic states as they may vary with climate or micro-climate must now be linked with the overt behavior of fighting men, and the military consequences of providing protection against natural or enemy imposed environments must be determined.

It should become apparent in the following discussion that attempts to relate disciplinary and engineering variables to soldier behavior have been marginally successful at best and have, in general, beeh badly hampered by sophistic reasoning and poorly defined terms. Consider, for example, the four approaches that have been taken in the "prediction" of military performance.

<u>Prediction from simple conjecture</u>. Some direct monotonic relationship is apparently thought to exist between states of comfort and generalized performance capability. The comfort associated with new

protective devices is usually a major consideration in their development. The assumption is made that the soldier will either not use "uncomfortable" protection; or, if he uses such protection, his performance will somehow he hindered in direct proportion to his discomfort.

Prediction from similitudes. The effects of a given variable on military performance are predicted from empirical knowledge of its effects on a form of behavior believed to be analogous. For example, relationships among air temperatures, hand temperatures, and finger dexterity are known for certain laboratory tasks. It is therefore presumed that something is also known about the relationships between climate and military performance. Something may be known, but surely in too gross a sense to be very useful. Let it be understood that the concept of using laboratory analogs to predict field performance is not being criticized here. Speculative prediction is. It is of great interest to us to determine empirical equations that permit our wealth of laboratory information to be used to describe, explain, and predict soldier behavior. Indeed, one of our most troublesome problems is that we have neither such equations nor the highly energetic search for them that seems appropriate.

Predictions from knowledge of imminent casualties or military ineffectives. Heat casualties resulting in a total loss of military competence can be quite reliably predicted as body core temperatures rise above 103°F during work in the heat. Much of environmental physiology can be used in this way, and the only real disadvantage is the all-or-none nature of the performance prediction.

Predictions based upon data from multi-disciplinary studies of selected military tasks and maneuvers. These studies get closer, of course, to the heart of the military performance problem, but even the best designed field research is vulnerable to fluctuations in such boundary conditions as weather and lighting. In addition, field research suffers from our not knowing, in any explicit sense, what constitutes military performance or its measurement.

In an attempt to resolve the problem of task validity, one group of investigators asked infantry officers and enlisted men with front-line experience to specify all the combat tasks of an infantry company and to rank them as to relative importance to combat missions, frequency of occurrence, and difficulty of accomplishment. Field performance tests were then constructed for a composite of the ten most frequent and important duties, excluding those tasks believed to be presently unmeasurable (Gruber, Dunlap, and Denittis, 1964). The study, conducted to establish a field testing course for the evaluation of new Quartermaster clothing and equipment, was designed more as an engineering enterprise than as a scientific investigation; it therefore falls short of providing us with the needed descriptions and measurement systems for soldier performance. The Institute of Environmental Medicine is in process of producing a more comprehensive

testing course that will include virtually all tasks named by the infantrymen in the above study. Sufficiently large groups of men going through this more complete course should provide the data from which basic performance components may be derived factor analytically. Hopefully the results may be used to construct empirically valid laboratory analogs of field performance.

EFFECTS OF HEAT ON PERFORMANCE

Prior to acclimatization, man's physiological defenses to extreme heat are very poor, and heat casualties usually occur long before there is any noticeable deterioration in psychological performance (Bass, 1963 a; Bass, 1963 b). Also, since the main physiological change to occur during heat acclimatization appears to be increased sweat production, we can expect early casualties in hot-wet environments regardless of acclimatization level; that is, increased capability to produce sweat cannot aid in body cooling when the vapor pressure of surrounding air is too high to permit evaporation of moisture. These facts suggest that studies of the relationships between heat exposure and performance should be conducted mainly with acclimatized subjects in hot-dry environments. The difficulty of specifying these relationships because of the physiological frailty of man in the heat is added to, as Pepler points out (1963), by the fact that measures of performance have been highly specific to each particular set of experimental conditions used. In spite of all the problems, there are considerable observational data on performance in the tropics that show reliable changes in mental alertness, morale, and physical work capacity during exposure to heat (Shepherd, 1962). It is a dreadful set of scientific findings, however, that still struggles to get beyond the facts of which any layman is obviously aware when he installs air-conditioners in his factory. Heat comfort is certainly related to physiological states and discomfort probably forewarns of physiological collapse, but whether there is any gradual degradation in overt behavior prior to collapse is yet to be determined (Bedford, 1961).

EFFECTS OF COLD ON PERFORMANCE

Although acclimatization to cold is subject to much controversy (Davis, 1963), two facts appear undeniable: The survival of animals at a given cold exposure is facilitated by prior cold experience; and the dependence of body temperatures on muscular heat production associated with shivering in humans is lost with successive exposures while the threshold for shivering rises.

Although most of the problems of adapting to life in the Arctic--isolation, sleep loss, anxiety (Rioch, 1961)--still require extensive investigation, the effects of cold on manual performance have been well studied, and the results clearly exemplify the psychologist's contribution. In many of the early studies, specialists in other disciplines were not aware of, and therefore did not differentiate between, the various forms of manual activity. Verifiability of findings was extremely difficult and little, if any, lawfulness was apparent in the data. Later psychologists found that manual performance on virtually any task is unaffected by cold if the skin temperature of the hands remains at 60°F or above (Clark, 1961). Between 60°F and 45°F skin temperature, only those tasks involving the movement of finger joints tend to show decrement. Below 45°F, where tactile sensitivity is suddenly and seriously affected, all manual activity suffers (Dusek, 1957; Fleishman and Ellison, 1962; Fleishman and Hempel, 1957). Obviously, any protective handwear that affects joint movement or interferes with tactile sensitivity will have similar effects. Auxiliary heating providing conductive, convective, and radiant heat transfer will usually maintain dexterity even in spite of total body exposure (Gaydos, 1958). A great deal is now known of the effects of cold on manual performance, and future advances should probably be made in other performance areas as well as in relating the dexterity data to combat tasks.

EFFECTS OF ALTITUDE ON PERFORMANCE

Those associated with aircraft and space research have long been familiar with the problems that altitude poses for the comfort, performance, health, and safety of man. However, while the engineering of cabins to keep man within his tolerance limits may be the answer for flight personnel, it surely is not the answer for field troops. Army researchers must determine the physiological, psychological, and behavioral effects of prolonged exposure at altitudes as high as 17,000 feet. We know that most men will fully acclimatize to altitudes as high as 15,000 feet in about fourteen days. Assuming that performance impairment ceases with acclimatization, we might resolve the Army's altitude problem by finding ways to produce the relevant cardiovascular and hematological changes artifically--through appropriate exercise regimes, for example. However, until we have done this we must at least describe what performance impairment does occur in unacclimatized troops during their first two weeks of exposure to altitude. What are the separate or combined effects of anoxia, cold, wind, high ultraviolet, and all the other characteristics that make a mountain a mountain? These are questions that must be answered--and soon.

CLOTHING, PROTECTIVE DEVICES, AND PERFORMANCE

Between the hazards of environment and a performing man may be interposed a device or system of devices designed to make the environment less stressful. Physiologists consider this protection an alteration in the environment, biophysicists consider it a change in the characteristics of the man, and psychologists consider it both. In any case, protection is rarely provided without some distortion of incoming sensation and a lessening of man's capacity to manipulate and control those portions of the environment that do not walk about with him.

HEAD PROTECTION

In protecting the head from combat hazards or natural environment, or both, it is often necessary to encapsulate the head, but in such a way as not to interfere with man's cranial sensorium. The protective device must act as a filter, excluding hazards while admitting cues. However, when the hazards consist of excessive energy levels of the same physical phenomena producing the cues, it is typically not possible to satisfy both protection and perception requirements simultaneously. Thus, protection from nuclear flash or lasers may be accomplished by momentary exclusion of all light energy from the eyes (Hill and Chisu, 1962), and protection from battlefield noises, frequently exceeding 140 decibels, may be accomplished by excluding all sound; but certainly the organism cannot then be expected to respond to light and sound cues unless they are separately received. At present, helmet engineering has not even been able to cope with very high intensity noises--let alone filter through relevant cues simultaneously (Cohen, 1960; Harris, 1955; Nixon, 1959). The problem is further complicated by a concept of "integrated headgear" in which multiple protection is to be provided against crash, projectiles, CBR agents, thermal nuclear weapons, lasers, natural environments, and noise, while permitting the soldier to see, hear, and breathe. It seems that, when we get the helmet adequately ventilated so that the man neither suffocates nor cooks himself, we have no place for noise attenuators or communication gear. Also, and perhaps more importantly, military priorities of ballistic and crash protection have always been higher than protection against noise. It might be an interesting engineering adventure to see what a helmet would look like if these priorities were reversed, that is, if we were to begin by providing effective communication and attenuation of external noise and secondarily add adequate ventilation and ballistic and crash protection.

The respective efficacy of the auditory and visual senses apparent in the conduct of man's activities is reflected in the fact that almost any visual restriction imposed by a protective system is regarded as intolerable, while major losses in the auditory sense may be overlooked. This is certainly understandable, and sometimes even reasonable. However, this point of view must be considered an exaggeration and, as with any extreme position, its relevancy must be continuously examined. For example, the

disregard of audition is probably never acceptable where effective voice communication is desired; and the reduction in size of visual fields due to hoods or face masks should not be considered intolerable on a priori grounds of preserving "normal" visual capacity but should be studied in terms of performance effects--visual field may be an irrelevant concept for a system (man) that "sweeps" 360 degrees (Crist, 1961).

Finally, a most significant gap in our knowledge of the effects of head protection devices on performance exists in the area of weight and weight distribution. No truly systematic research appears to have been done that would permit the helmet designer to estimate weight limitations.

BODY PROTECTION

All clothing and special protective systems for the body are likely to influence man's thermal regulation. Each new type of garment must therefore undergo physiological evaluation. The typical procedure is to have men work and rest for varying intervals under the climatic conditions anticipated for field use of the garment. Physiological tolerance times are reported to the clothing designer, and a decision is made whether the item is ready for its military users or should be continued in development. Comfort usually becomes an important consideration in this decision (Santa Maria, Klein, and Greider, 1960), and any protective device--effective or not--which is found to be "uncomfortable" is almost certain to return to some earlier stage of its development cycle.

Bulkiness and flexibility are important considerations in some clothing ensembles because they can quite seriously restrict movement and may produce extreme fatigue. Numerous motor tasks have been developed to study the effects of these variables as they appear in Arctic clothing (Dusek, 1958) and in pressure suits (Bommarito, 1963). In general, the tasks selected should assess rate of movement, psychomotor coordination, work-space involvements, anthropometric flexibility, manipulative area, level of exertion, manual dexterity, and visual restrictions (Siegel, Bulinkia, Hatton, and Crain, 1960). But whatever the task, it continues to be extremely difficult to relate behavioral variance to specific design features of clothing; and it is rare that the behavioral researcher can provide any explicit guidance to the clothing technologist.

An important new approach in the design of body armor from rigid materials has appeared (Barron, 1962). The technique involves the drawing of a grid system on the skin of a subject and observing the distortions as the subject takes positions assumed to be related to soldierlike activities. The data have permitted designers to reduce the number and sizes of overlapping pieces and have provided insights into flexibility characteristics of armor systems.

HAND PROTECTION

Protecting the hands from physical hazard inevitably affects ability to use the hands. A compromise must be reached as to how much loss in dexterity we can afford. An area of research which should improve future handwear has been the study of the distribution and physical nature of insulating materials (Groth and Lyman, 1959; Groth and Lyman, 1958; Lyman, 1957; Lyman and Groth, 1958). Surface friction of finger covering material, thickness, flexibility of back covering, and laminar configurations have been found to be important determinants of manual capability. This type of research provides a basis for predicting the effects of new types of handwear on manual skills even before prototype fabrication, and must be continued as a most promising enterprise in the human engineering of hand protection.

FOOT PROTECTION

Except for some observations on foot comfort, behavioral scientists have done very little work on problems of military footgear. Research has been limited mainly to specialties like podiatry and anthropometry (Skrettingland, Clogston, and Veghte, 1961). However, this is not to say that there is nothing the behavioral scientist can contribute here. A soldier's overt performance in standing, running, and jumping is certain to be affected by his footgear. First, we must determine the characteristics of footwear with which we must deal. We often speak of traction. What is it? How do we measure and manipulate it? What is meant by support? What are the psychological and behavioral effects of foot fatigue? There are many research questions to ask here, and frequently it is the behavioral researcher who should answer.

PERSONAL EQUIPMENT

The sleeping bag, load carrying equipment, evacuation bags, shelter, and life preservers all present problems of interest to psychologists and human factors engineers. However, performance studies take a somewhat different form than in the case of protective gear. Main concern is with performance in utilization of the personal equipment rather than with effects of the equipment on some more fundamental military task.

Comfort studies and the treatment of comfort reports are also different. Certainly, if comfort is relevant to anything, it should be relevant to the quality and duration of sleep. States of "discomfort" associated with the utilization of sleeping bags may be of quite fundamental importance (unless, of course, it is found that "discomfort" is unrelated to sleep patterns).

FUTURE RESEARCH

While, as in the past, the psychologist may be called upon to evaluate prototype clothing and equipment, the more significant future advances will come from research aimed at producing data which influences original designs. This objective requires much better definition and control of variables than has ever been achieved. In addition, emphasis on integration of previously separate protective systems into all-encapsulating uniforms foreshadows a new era in clothing and equipment design--an era in which the tailor is no longer the designer and the engineer does not overcome his problems by increased electric power, but where design features are anticipated from knowledge of the life sciences, clothing and equipment technologies, and their interrelations. The development of a science of clothing will be maximally successful only if truly systematic. System and subsystems need definition. Interdisciplinary research must somehow replace multi-disciplinary thinking, speculation must become less satisfying, and empirical findings must become the standard of acceptability.

RESEARCH ON FOOD ACCEPTANCE

The military services have long recognized the importance of acceptable food for the morale and health of their personnel. In a continuing attempt to maximize food acceptance, they have sponsored research on methods of measuring and evaluating food preferences, on the psychophysiology of hunger, thirst, and satiety, and on food habits and patterns of consumption.

Methods of measuring preference (Pilgrim and Peryam, 1958) include such hedonic scales as that developed at the Quartermaster Food and Container Institute (Peryam and Pilgrim, 1957). This scale and numerous variations of it have been used rather widely in laboratory and field studies because of its basic simplicity and meaningfulness even with totally inexperienced subjects.

Acceptance testing is used in a wide variety of situations--pre-award evaluation of products prior to purchase, studies of off-flavor changes in foods with prolonged storage or unusual packaging, flavor and texture evaluations associated with new processing and preserving methods like freeze-dehydration, and evaluations of novel and special purpose foods such as the space flight diets and "quick serve" meals.

Since 1950, the Army has conducted nine surveys on the food preferences of soldiers. As a result, we now have preference ratings on some 450 different food names distributed across all major food classes and categories. (For a summary of the first eight surveys see Food Preferences

of Men in the U. S. Armed Forces, by Peryam and his associates, 1960). The last survey, conducted on nearly 20,000 military personnel, should reveal modern consumption patterns as well as the acceptability of some of the new foods introduced in the Army's Master Menus.

Much as has been accomplished in this area, there is a great deal left to do before we have filtered "true" effects from the bias of methodologies, and certainly before we can predict and explain preference in food consumption. Again, systematic work is needed in the interdisciplinary investigation of the gustatory and olfactory senses, and more use must be made of available techniques such as gas chromatography for the physical and chemical description of the foods. The next step in this area would seem to be coordination of gas chromatographic profiles with known individual preferences. Such coordinated research would provide a more fundamental scale for the classification of preferences and should permit a determination of the separate and mutual effects of texture and flavor. In any case, improved description of terms appears to be as important to advances in the area of food preference as to progress in environmental protection.

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CHAPTER 11

BERNARD J. FINE

ADJUSTMENT TO MILITARY STRESS

This chapter is concerned with a review of military research efforts to predict differences in performance under stress--combat, isolation, heat, cold, altitude, hunger, fatigue--on the basis of personality-related information. In recent years, the area has been largely static. For the most part, investigators have been concerned with developing paper-and-pencil measures or modifying existing ones, factoring newly assembled sets of variables or replicating previous factor analyses, measuring performance on standard tasks--activities all directed toward prediction of response to stress on the basis of personality factors. Much attention has been devoted to problems of the reliability and validity of the predictive measures and to problems of performance criteria. Progress has been slow and no outstanding breakthroughs have been evident. However, on the encouraging side, several signs point to an increased sophistication in this area, an area which has great potential significance to the military.

ONGOING RESEARCH

Weybrew, at the Naval Medical Research Laboratory in Groton, Connecticut, has a continuing program, several aspects of which are personality oriented. The program deals both with the prediction of success at the submarine school and with investigation of individual differences evidenced in response to the many stresses inherent in the submarine environment. His current effort includes the modification and purification of existing measures and the development of new and more effective ones. Future plans include collaboration with submarine medical officers on Fleet Ballistic Missiles (FBM) duty in carrying out shipboard projects. The relationship of objective test indices of adjustment to individual differences in subjective symtomatology during a two-month cruise has been studied, as well as the relationship between marital adjustment and individual differences in adjustment during an FBM cruise.

Weybrew has recently placed some emphasis on the importance of the autonomic nervous system (ANS) in response to stressors and has undertaken a study of ANS variability in one person over time, using palmar EDC and heart rate as indirect measures of ANS activity. Results indicate marked day-to-day variation in levels on both ANS and subjective feelings measured by a checklist. The finding may support the feeling of some investigators--and it can be only a feeling, since there has been little systematic evaluation of the reliability of such measures--that phenomena of this kind are

too variable to have much value in a predictive system. However, there appear to be systematic differences in variability among individuals.[1] These differences are extremely important, particularly in activities requiring minimal variability in day-to-day responses of military personnel--monitoring of equipment, for example. At the present time it appears possible to select, a priori, individuals who are less variable than others, at least with respect to certain kinds of behavior.

Haythorn, at the Naval Medical Research Institute in Bethesda, Maryland, is conducting a five-year study of individuals and small groups working at isolated stations. The program, which has a strong theoretical orientation, is founded in part on social comparison and cognitive dissonance theories. Recent research has included a study of the effect of a 10-day isolation period on dyads varying in personality composition according to need achievement, need dominance, need affiliation, and dogmatism. The interest here is on the effects of similarity and heterogenity in the personality composition of the group on performance in social relations. Three tasks were used: a one-man vigilance task, a cooperative reasoning task, and a simulated CIC task. Responses on a number of personality instruments were also obtained.

Future plans call for field validation of the laboratory results and research on psychophysiological and psychopharmacological correlates of behavior under stress. Isolation studies of individuals and teams continue, the ultimate objective being the construction of groups which will perform with maximum efficiency while getting along socially. The development of computer models of group interaction processes will also be investigated.

The Navy Medical Neuropsychiatric Research Unit in San Diego, California also has an ongoing program with some emphasis on personality adjustment to stress. The research is conducted primarily by Gunderson and Nelson who for some years have been studying small groups stationed in Antarctica. In the attempt to develop a criterion measure of individual performance for personnel who winter over at small Antarctic stations, the best single measure to date is a standard score representing a combination of supervisor ratings and nomination by peers. In the peer nomination, each member of the group indicates the individual with whom he would most like to return for further small station duty. Attributes of behavior considered to have greatest promise of predicting performance are emotional composure, social compatibility, and task motivation.

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[1] For example, see Fine, B. J. Internalization ratio, accuracy, and variability of judgments of the vertical. Perceptual and Motor Skills, 1963, 16, 138, and Worell, L. Intra-individual instability and conflict. Journal of Abnormal and Social Psychology, 1963, 66, 480-488.

Fine and Sweeney at the Army Research Institute of Environmental Medicine in Natick, Massachusetts have adopted an interdisciplinary approach, with emphasis on biochemical factors relevant to the study of the psychological aspects of emotional behavior. The program is an attempt to extend early research in this area and to anchor the research in theory. They have taken reasonably reliable and valid measures and proceeded to inquire into relationships between these measures and physiological and biochemical behavior. During the past year, they have investigated the relationship between anxiety and introversion-extraversion and the urinary excretion of catecholamines (adrenaline and nor-adrenaline). Focus has been on non-stressful situations in order to establish baselines for later work in stress, although some work has been done using cold as a stressor. Using a theoretical framework which ties together the concepts of anxiety and introversion-extraversion and consistently using the same measures of these traits, Fine and Sweeney have elucidated systematic individual differences in such diverse areas as selection for duty on the Greenland icecap, recovery of core temperature following cold exposure, incidence of motor vehicle driver accidents and violations, satisfactory performance as test subjects, and accuracy and variability in the perception of the vertical. Using the same variables, measures, and conceptual schema, they have recently found two divergent anxiety relationships, one associated with introverted personality and one associated with non-introverted. The introverts showed a significant and high negative correlation between anxiety and the criterion of cold-induced vasodilatation in the hand, whereas the non-introverted types showed a significant and high positive correlation between anxiety and the same criterion. This finding has led to a more complex concept of anxiety. In addition, introversion and non-introversion are related to identifiable, quantifiable, and predictable biochemical processes; in the introvert group, a multiple correlation coefficient of .92 was obtained between anxiety, adrenaline, nor-adrenaline, and the criterion of cold induced vasodilatation in the hand; in the non-introvert group, the comparable coefficient was .84. Future plans include further exploration of adrenergic behavior and an extension into cholinergic-related variables.

In addition to the four programs mentioned, a number of research programs are concerned with personality adjustment in conjunction with other ongoing research. Individuals scattered throughout the services--at the Air Force School of Aerospace Medicine, at the Naval Aviation Safety Center, and at Walter Reed Army Institute of Research--are engaged in research on personality variables in relation to stress. Yet, it must be concluded from the paucity of programs reported that research on personality adjustment to stress is deemphasized in military research and development.

CRITIQUE OF CURRENT APPROACHES

The reasons are undoubtedly many. Much of the fault lies with the area of personality research itself and its stereotyped approaches.

Theorizing has been maximal and experimental rigor minimal, and the theories have rarely accommodated the practical problems the services generate. Much of the early experimentation, even though containing valuable insights into human behavior, was not acceptable to the more rigorous experimental psychologists. Research on stress came to be regarded as essentially non-scientific. This conception, coupled with the fact that a good many of the administrators of psychology programs in the military have been of experimental rather than of clinical orientation, has led to the rejection or, at best, minimization, of personality research efforts in the services.

The situation has changed somewhat in recent years. Personality research has become more scientifically acceptable with a resultant increase in productivity. This change has been partially due to the fact that many clinicians have become research oriented. Too, many experimental psychologists, for one reason or another, have adapted personality variables to their own areas of interest and used them in their research. Thus, the personality research area can be said to have acquired respectability by association.

But what has been the cost of this new-found respectability? Offsetting the increase in productivity, there appears to be a rather unfortunate lack of emphasis on content. Some experimentalists, not being clinically sophisticated, have taken clinical variables out of context and reduced them to extremely simple terms in the service of methodological elegance. Take the concept of anxiety. One can find innumerable articles in the past ten years in which the Taylor Scale of Manifest Anxiety, to cite a popular example, has been used. Regardless of the cautionary warnings of Taylor and Spence on interpretation of the test, the Taylor Scale apparently _is_ anxiety to many investigators, who appear to have little idea of anxiety in the clinical sense.

This ultra-simplification of complex areas of human behavior in the interest of experimental expedience has not led to any great advances in personality research. In fact, the negligible progress in this area can be said to have reinforced the contention of many experimentalist-observers that the field has little to contribute to the solution of military problems. They can say that since their "tough-minded" experimentalist colleagues working in the personality area have achieved no significant breakthroughs, the area must have little to contribute. Since many administrators of psychology programs in the military are experimentalists, as has been noted, we have what could be described as a built-in, self-perpetuating mechanism inhibiting the growth of the personality research area.

This itself may be an over-simplification of what is undoubtedly a very complex historical phenomenon, but the point is clear. The initiative in reversing the trend must come from the researchers in personal adjustment to military stress. If they are to play a larger role in military research, they will have to demonstrate that their variables are truly significant. This step calls not only for an enhancement of content, but

also for a familiarity with and understanding of military problems. Administrators are not going to beat a path through the morass of tests, inventories, indices, theories, undefined variables, and unorganized emprical facts to demand more research with greater depth and applicability. Even research of indisputable merit will not be accepted if it does not have utility for solving military problems.

CURRENT STATE-OF-THE-ART

We are now in an era where specialization is an integral part of the military picture. Emphasis is on isolated combat teams, remote early warning stations, complex equipment, long-term submergence, and long-term space flight. Special kinds of individuals are required who can endure stresses and maintain their abilities to function optimally. For space flight, for example, experienced pilots who had proved themselves in aircraft appeared a natural nucleus from which to select personnel. But the personality characteristics required for space flight are still much less known than those for airplane flight.

As for the fighting man, concepts such as aggression, hostility, anxiety and fear came readily to mind. Yet as far as can be determined, there is no ongoing study of aggression per se as a personality variable, with the possible exception of Fine and Sweeney. It is not the intention here to belittle current approaches to personality research which employ variables other than aggression, anxiety, and fear. Obviously, factors such as morale, motivation, leadership, and compatibility can be studied from the personality point of view with worthwhile results. But variables such as anxiety, aggression, and fear may underlie the higher level variables and little effort, comparatively speaking, has been devoted to researching these possibly underlying factors.

A LOOK AHEAD

To study these factors, it may be necessary to broaden the concept of personality to include levels of behavior organization other than the psychological. It is apparent from the literature that strong relationships exists between psychological states and physiological and biochemical states with respect to emotional behavior and that effort devoted to investigating these relationships holds promise of substantial pay-off to the military establishment.

However, psychologists have been reluctant at least until recently to engage in this kind of research. There is a tendency to do so now, as evidenced by the emphasis being placed on certain indirect measures of autonomic activity. But much of this work appears to be taking the superficial form criticized above. Heart rate and blood pressure are becoming popular measures in the psychological literature. It is obvious, in some instances, that these variables are being taken out of context and oversimplified as indices of autonomic activity. As with anxiety studies, it

is likely that, in some instances, these indirect measures will become synonymous with autonomic activity.

This reification is a major obstacle to progress in this area. Even a casual perusal of the literature in physiology and biochemistry dealing with the autonomic nervous system gives an impression of the enormous complexity of the area. Over-simplification is like cutting the Gordian knot in attempting to unravel this complexity as it relates to psychological behavior.

What is needed is work in depth, an approach that presents a dual challenge for the psychologist. On the one hand, he must retain his identity as a psychologist. He must tolerate accusations by his peers of engaging in reductionism. On the other, he must become informed in areas other than psychology (such as medical and biological) in order to communicate and to understand the nature of the variables with which he is working. The need to persist in his efforts in the face of administrators who fail to recognize the value of this approach will be a third challenge, but a familiar one.

Perhaps a new breed of investigator is needed, trained as an interdisciplinarian with emphasis on psychology, physiology, and biochemistry. Whatever the answer, the problem seems worth additional consideration.

It seems clear at this writing that the subject matter of the area must become more substantial, more basic, more global, and more intensive with respect to those personality factors which appear to have most relevance to the military situation. The concept of personality must be broadened to include other disciplines, and researchers in the field of personality must similarly be broadened.

It is evident that a few researchers are heading in this direction. We can take some encouragement from this fact. But unless the effort intensifies, the immediate future does not appear overwhelmingly promising.

SOURCES OF INFORMATION

AIR FORCE

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PART V

CONTRIBUTIONS OF ENGINEERING PSYCHOLOGY TO MILITARY SYSTEMS

INTRODUCTION TO PART V

Dr. Julien M. Christensen of the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, was principal participant and chairman of Part V on the contributions of engineering psychology to military systems. Dr. Christensen has combined all contributions into a single chapter. In his introductory comments, Dr. Christensen reviews the history of human engineering suggesting some forward-looking concepts which are implied by the current state-of-the-art. To single out one thought-provoking question: "While an individual may control more machines, greater computers, more power, perhaps even more people, etc., do not these same elements with which he is interacting also exert greater control over him, essentially reducing individual freedom of choice and action?"

The section on current status and future trends continues with suggestions of techniques and systems which are evolving as a result of the accelerating growth and interactive influences in the field. Considerable emphasis is on computer techniques and cybernetics as leading to the greater flexibility of systems, which may now be designed to take advantage of individual differences and variability rather than adding man in as a constant--as well as providing greater flexibility in other aspects of system operation. This section was prepared by Dr. James W. Miller, Dr. Marshall J. Farr, and Dr. Lee R. Beach, Office of Naval Research.

The section on methodology was the work of Dr. Leon T. Katchmar, U. S. Army Human Engineering Laboratories (Aberdeen Proving Ground). Dr. Katchmar takes up the following stages: military systems requirements, concepts, preliminary design and development, test and evaluation, production engineering, and operational use.

In an integrative summary, Dr. Christensen focuses on the areas in engineering psychology in which progress is needed and can be anticipated: the training of engineering psychologists, further development of methodology at the conceptual and test and evaluation stages, coordination of the efforts of engineering psychologists with those of design engineers, research on computer-man relationships, and application to commercial systems to improve mankind's relationship to a highly engineered environment.

CHAPTER 12

JULIEN M. CHRISTENSEN, JAMES W. MILLER, MARSHALL J. FARR, LEE R. BEACH, AND LEON T. KATCHMAR

DEFINITION AND HISTORY

In this chapter we attempt to define the genesis, early development, and current and future trends in engineering psychology. We have made no attempt to provide specific design information, as we feel that sufficient sources already exist for that type of information in such publications as the Human Engineering Guide to Equipment Design, the Handbook of Human Engineering Data, and many others. Rather we have tried to describe the origins of engineering psychology, where it is now, and what can be expected of it in the near future.

What is the nature of engineering psychology? Fitts says it " . . . seeks to understand how human performance is related to task variables (especially engineering design variables) and to formulate theory and principles of human performance that can be applied to the design (my underlining) of human tasks, human-operated equipment, and man-machine systems" (Fitts, 1963)." Later, in the same paper, Fitts reminds us that the engineering psychologist " . . . is also interested in parameters that influence the relations between task variables and performance, such as individual differences, motivation, and level of training." In this dawning of the era of automation, Fitts also includes the social consequences of design as an area in which the engineering psychologist shares responsibility with many other professional people.

Let us now formulate several basic precepts regarding engineering psychology. First, unless the research results of engineering psychology can be expressed in engineering terms, and thus can affect design, the results do not contribute, at least directly, to engineering psychology. Second, engineering psychologists do research and they serve as staff advisers and consultants to design engineers. Third, engineering psychologists occasionally engage in design work themselves. Years ago Taylor termed such engineering psychologists "human engineering technologists." They contribute to systems development at three levels: "At the simplest, he designs individual displays, controls, or display-control relationships. At a somewhat more complex level, the human engineering technologist contributes to the design of consoles and instrument panels. At the highest level of complexity, he assists in structuring large systems composed of many mechanical elements and frequently several human beings. In this capacity, he helps to determine what information must flow through the system, how it must be processed, how many men are required, what tasks they will perform, and what type of information each one will need. In short, the engineering psychologist helps at this level to determine the

configuration of the system" Taylor, 1957. Some engineering psychologists have been, and others could be, excellent systems planners and designers. We are not willing to accept the design of dials, the design of consoles, and the offering of assistance in structuring larger systems as the ultimate to which a competent engineering psychologist can aspire. We see no more reason for keeping an otherwise qualified engineering psychologist out of the business of systems planning, design, and management than we can see for keeping a physician out of the business of designing a steel shaft to replace a broken bone.

Let us look for a moment at the history of the profession that engineering psychologists support, namely, engineering. History can be revived, Boring (1950) reminds us: "As time goes on, there come to be second thoughts about the interpretation of it." This interpretation is a reflection of the distinctive, perhaps idiosyncratic, interaction between certain "facts" and the writer. Another psychologist, and almost certainly any engineer, might interpret them differently.

First, let us define "engineering." Fitts reports that as early as 1828 the Institute for Civil Engineering of London considered the practice of the profession as more than the strict application of physical sciences. They defined engineering as "The art of directing the great sources of power in nature to the use and convenience of man." It is of more than incidental interest that they too recognized engineering, in part, as an art--the "gut-feeling" of 1828! One hundred thirty years later, the Institute of Industrial Engineers stated, "Philosophically, he (the industrial engineer) is devoted to the ideal of helping the nation to use most effectively its physical facilities and human talents for production of goods and services." This, you will recognize, is a recasting of the 1828 definition. It explicitly includes human talents. In these days, no design engineer should assume the title "systems engineer" or "systems manager" unless he is sensitive to and capable of handling those subsystem and system interactions that involve the organic as well as the inorganic. This nation has thousands of splendid design engineers; there is a critical shortage of systems engineers.

The above definition would appear to include the design and utilization of tools as an enterprise that legitimately falls within the purview of engineering. If we accept this as so, we can trace engineering back to earliest man, or (depending upon the particular archeological or anthropological authority to whom you subscribe) even to the man-apes. Australopithecus Prometheus, for example, used pebble tools, employed thigh bones as weapons, and used scoops made from antelope cannon bones (Christensen, 1964). Thus, we might conclude that engineering and the human factors components thereof, as reflected in the design and use of the first tools, actually determine the dating of the origin of man. This, incidentally, is the position subscribed to by many anthropologists; they have despaired of defining meaningful anatomical distinctions and refer instead to cultural achievements.

Aside from serving as a possible source for dignifying engineering and our profession by anointment with antiquity, what possible lesson can be learned from the events of one million years ago? We suggest that pebble tools and scoops made from antelope bone were specific, intelligent reactions to <u>interactions with the environment</u> and that current principles are no more than that--response to interactions among and between the organic and the inorganic--responses that have become, when compared with the bone scoop, unbelievably and fascinatingly complex.

We now blithely skip forward a few log units in time (a million years) to consider the impact of the industrial revolution in terms of interactions and man's response to them. (Neglect of hundreds of thousands of years may be justified when we consider the relatively slow rate of development during the Age of Tools. Causes of this lag in development need not concern us here.) We rely heavily on a previous report of one of the authors for this information (Christensen, 1962).

PHASE I - THE AGE OF MACHINES

The first phase of the industrial revolution, which covered a period of approximately 120 years (1750 to 1870), witnessed the emergence from the Age of Tools to the Age of Machines. This period was characterized by brilliant invention in the textile industry and the application of steam power to the operation of machines. In this period, Jacquard used punched card techniques (1801) as a programming aid with weaving equipment, and Watt designed a self-regulating governor for his steam engine--the beginnings of automation and Cybernetics! Engineering, although crude and not formally recognized, was attempting to relieve the muscles of mankind. The word "psychology" was not even invented, although this should not engender dismay. There were people, as we have seen, who met the fundamental criteria of "engineer" long before there was such a profession.

PHASE II - THE POWER REVOLUTION

The second phase of the industrial revolution has often been called the "power revolution." This period encompassed the years 1870 to 1945, and was characterized by fantastic developments and increased efficiency in transportation, communications and agriculture. Human factors pioneers from the disciplines of engineering and psychology made their first formally recognized contributions of a psychological nature. One calls to mind such names as Taylor, the Gilbreths, Muensterberg, Binet, and others. Although the primary emphasis was on the adjustment of man to his work by utilization of the techniques of selection, classification, and training, we would be something less than candid if we did not recognize that Taylor and the Gilbreths made certain contributions that now would be considered applications of engineering psychology.

By 1945, engineering psychology had been formally recognized. Thus, it might be well to pause and briefly to summarize its nature at that time. This was the "knobs and dials" era. In retrospect, it may seem to some to have been an era of simplicity; at the time, however, it represented a pioneering effort that required all the insight and mental resources that could be mustered. The major emphasis of behavioral scientists through World War II had been on selection and classification tests and training procedures, or adapting man to job. The few isolated investigations in engineering psychology in the United Kingdom and in the United States contained little evidence that the investigators recognized they were pioneering a revolutionary enterprise.

As far as the human was concerned, the engineering sciences gave primary attention to the pioneering work of Taylor and the Gilbreths.

PHASE III - MACHINES FOR "MINDS"

Several events that occurred during and since World War II have so increased the complexity of cultures (and thus increased the number and complexity of individual and group interactions) that it appears that this period should be termed Phase III of the Industrial Revolution. We are living during this period and thus do not have the benefit of hindsight to assist us in interpreting the true nature and extent of its impact on the cultures of the world.

The events of Phase III that are of special interest to us are the development of atomic energy, the development of high-speed computers (a powerful tool for use in communication, industrial, military, economic and perhaps even social systems), automation, and space explorations. We are witnessing the wholesale substitution of machines for some of those functions of man that previously had been considered his "higher" processes.

THE RESPONSE OF ENGINEERING PSYCHOLOGY

Elsewhere one of the authors has covered the response of engineering psychology during this period and we will only briefly summarize this area (Christensen, 1958, 1962). There has been a progression from retrofit of original design to design of elements ("knobs and dials") to design of components and subsystems to a clear recognition of the requirement to fit machines to men. We must now take a fourth step and recognize that in order to realize maximum efficiency and satisfaction, machines and men must be fitted to concepts. We are almost ready to divest ourselves of those preeminently useful lists of the past which explained what men can do best and what machines can do best and, in their stead, these elements

of design will be considered only in relation to the conceptual requirements of a particular system as those requirements exist at a particular point in time.

Some will say that this represents a distinction without a difference. We cannot agree. True, the aims of our profession during the first three phases were the same as they are now, i.e., participation in the development of systems that, in terms of specified criteria, are maximally effective. Even now, however, the nature of complex systems is being considered in some detail at the conceptual level and then, and only then, do the designers determine the components and materials to be used to meet the requirements of the system, and only then do they determine whether those elements should be organic, inorganic, or a combination of both. In the future, systems planners will use simulation more and more as a design tool that will enable them inexpensively and quickly to assess the merits of alternatives without committing substantial resources to any of them. This implies a knowledge and understanding of systems principles (and advancements in simulation) that are not available today. Perhaps we should next turn to this topic.

Why do we need systems research and its companion, research in simulation techniques? Why, in the last decade, have these areas suddenly received increased attention? Perhaps the implications from our previous meanderings among anthropology, archeology, engineering, psychology, will support the position we now adopt. Such research is necessary simply because the interactions among our cultural elements (whether organic or inorganic) have become so manifold and so complex that successful and economical design of a system of even modest complexity is impossible without the benefit of sound scientific principles and appropriate supporting tools. Accepting this as a tenet, one then is forced to conclude that professional members of each of the sciences that support the development of systems must assure that their own house is in reasonable order. The principles of each discipline must be so stated (or, by means of transformations be capable of being so stated) that they can be considered appositively with the principles of other contributing disciplines.

Other areas directly in support of systems planning and design that need particular attention are control dynamics, complex visual perception, decision-making, the proper function of computers, design for motivation, and design for work in unusual environments. (This latter, incidentally, must include assessments of the effects of multiple stressors applied simultaneously or sequentially. Specifically, are the effects on performance additive, logarithmic, or synergistic?)

In a somewhat different vein, we need cross-cultural studies, much like those Hertzberg and his team (1963) have performed in the field of physical anthropology, in order adequately to assess the effects of different cultures, customs, educational systems, etc., on systems design and development. Most current engineering psychological data are drawn from studies based on English-speaking people only, and these have been restricted chiefly to Great Britain, Canada, and the United States.

To continue, many writers have suggested that we very much need to develop better methods of communicating with computers, both input and output. Someday we will see Kelley's ideas on predictor displays elaborated to include the results of the analysis and synthesis of data from literally hundreds of sources.

In addition, what might be termed "double design" possibilities offer interesting opportunities for engineering psychology. An engineering psychologist, working in the area of remote manipulation, should consider the possibilities of redesigning the objects that must be manipulated as well as attempting to improve the remote manipulators.

We suggest also that any branch of science progresses only as its tools and methods improve. While we have one text that might be termed a "methods" book (Boring, 1950), we feel that engineering psychologists do far too little work of a methodological nature. We know far too little about the validity of the methods we employ. For example, we frequently employ user opinion as a criterion, but do we really know where and under what conditions it is an effective criterion? We engage in system tests, but we do little to investigate the possibilities of improving our test procedures. We find that traditional laboratory techniques cannot be used, so we seem to despair.

In systems planning, man is coming more and more to be considered for his cognitive capabilities and his abilities to handle conditions that cannot be expressed alpha-numerically. This implies the design of systems in such a manner that man at any moment can effectively exercise his judgment, for this is one of the greatest assets he brings to systems. Bray of The Smithsonian Institution has termed this the "development of context" in systems design. Finally, let us try, through research, to show systems planners and designers that variability is an outstanding human characteristic that should be used as an asset instead of viewed constantly as a liability. Without variability there would be no learning and no adaptation--two prerequisites for designing into systems one characteristic that distinguishes the mediocre from the outstanding. We speak, of course, of flexibility.

In another publication, one of the authors has attempted to trace the history of systems research, to define some of the chief problems in this area, and to forecast future progress (Christensen, 1958). This information will not be repeated here, but we will extract a thought or two that seem particularly germane.

The theories of behavior applicable to complex man-machine systems not only must be useful to systems engineers but also should provide a link with existing behavioral knowledge. No new approach can afford to divest itself of the tremendous fund of sound, relevant behavioral knowledge that exists.

Research is needed in mathematical model-building with special emphasis on the solution of complex problems involving higher-order interactions.

Mathematics will surely prove to be our common communication medium with engineers, physicists, and other scientists.

We hope, however, that our approach to systems research in particular is not in danger of becoming stereotyped too soon, that is, we must not insist on a strict operationalism too early in the game. Bateson's expressions regarding the nature of scientific thought (1941) may be worth considering in this respect: " . . . whenever we pride ourselves upon finding a newer, stricter way of thought or exposition; whenever we start insisting too hard upon operationalism or symbolic logic or any of these very essential systems of analysis, we lose something of the ability to think new thoughts. And, equally, of course, whenever we rebel against the sterile rigidity of formal thought and exposition and let our ideas run wild, we likewise lose. As I see it, the advances in scientific thought come from a combination of loose and strict thinking, and this combination is the most precious tool of science." Engineering psychology, in our opinion, must also support its share of this type of "loose thinker."

Finally, it may be of more than academic interest as to what the exponential increase in interactions referred to earlier means to the individual members of society. Does unit freedom increase or decrease as the number of interactions in which the individual becomes involved increases? While an individual may control more machines, greater computers, more power, perhaps even more people, etc., do not these same elements with which he is interacting also exert greater control over him, essentially reducing individual freedom of choice and action? Such considerations are perhaps beyond the immediate interest and current responsibilities of the engineering psychologist and the system engineer (and certainly are beyond their capability). Yet to ignore these interactions would patently violate the ultimate intentions of our professions.

CURRENT STATUS AND FUTURE TRENDS

In the following discussion we suggest some techniques and systems which may evolve as a result of the accelerating growth and interactive influences within our field. It will consist of two parts: (1) a critique of some of the current problems inherent in our data, and (2) a look into the future.

PRESENT DATA

Four major problems currently characterize the process of gathering, dealing with, and disseminating the data of engineering psychology. These four problems, though probably overgeneralizations, may provide clues to the future.

The first problem relates to the fact that very few scientists have been trained as engineering psychologists. As a result, each holds the ideas, language, and biases from his specific field of training. The diversity of terms and the jargon found in the literature sometimes lead to a breakdown in communication. Not only are terms liberally borrowed from other disciplines, but frequently the odd assumption is made that some other discipline, less familiar, is somehow more "scientific" or "respectable" than one's own. Expressions deriving from the admired discipline are liberally sprinkled around to the point of misunderstanding or misuse until serious doubts are raised as to what the terms really mean. Thus, we find human engineers, trained as psychologists, "technologizing" their efforts by talking of human beings as though they were nothing more than electronic devices or relatively inefficient machines. Other human engineers, borrowing from the medical sciences, rely upon biological analogies in treating a group of people as though it were a single organism. Others tend to view human beings as statistical processes. The value of such concepts is not on trial here. These analogies are bound to have limitations. Unfortunately, such limitations often are not recognized by those who would apply the analogies.

We can be quite hopeful in looking forward to an engineering psychology language which is uniquely appropriate to a specialty required to bridge the gap meaningfully between man and machine. Certainly, specialized language cannot always be avoided and, in fact, sometimes should not be avoided. But confusion of terms, jargon-for-jargon's sake, and specious analogy can and must be eliminated. The psychologist <u>can</u> write for an engineering audience without compromising unique human capabilities. Similarly, the engineer can communicate effectively with the "software" specialists without doing injustice to his profession.

The second problem concerns the relationship between cost and experimental validation. Those of us who are associated with business or government are aware of the fantastic cost of research; yet, because of lack of communication of research results, we find that many people are doing essentially the same work in many parts of the country without knowledge of each other's studies or findings.

Research costs are high; it is extremely important that research results be made available as soon as possible so that they can be verified, utilized, and the research not unnecessarily repeated. All too often, proposals are received by government agencies in which a substantial amount of time and effort is to be devoted to literature searches and state-of-the art familiarization. No one can deny the need to be aware, when starting a new program, of what has gone before. But it is unfortunate indeed that all too often each search is planned and conducted as if one had never been done before. Paradoxically, the huge masses of data being produced are overtaxing publication channels, thus producing a significant lag in publication time. The printing of additional journals partially alleviates the problem. As each new journal specializes in a particular scientific area, the specialist can read fewer journals and maintain a

more up-to-date knowledge of his specific field. The relatively recent introduction of the journal, Human Factors, is an example.

This brings us to a third general problem, that relating to the data of engineering psychology. Many of the individuals most thoroughly trained in scientific methodology and data analysis are unaware of the practical situations to which their results could apply; or if they are aware of them, they choose not to become involved. Other individuals whose job it is to conduct tests and evaluations appear incapable of thinking beyond the needs of the immediate practical problem. Their experiments deal only with limited ranges of the experimental variables, and fail to explore the whole spectrum of possible conclusions; consequently, even their best research fails to be of any appreciable value to other workers in the field. If both the research-oriented and the system-centered specialists could cast off these self-made shackles, they could truly coordinate their efforts and complement one another. We could then reasonably expect an almost immediate return in time and money saved.

In addition to a thorough examination of the ranges of the experimental variables, it also is necessary to examine interactions among them. These interactions are fundamental aspects of an investigation, and are basic to the successful utilization of the experimental results by other engineering psychologists. It is clear that the design of any system using knowledge from the literature will necessitate compromises between what is known and what is required by the system under consideration. It is a serious responsibility of the engineering psychologist to keep these interactions in mind so that wise compromises can be made.

The fourth problem concerns the fact that the growth of engineering psychology as a profession is basically dependent upon the growth of an adequate body of literature. Some question exists as to whether or not an adequate literature is developing fast enough.

For years we have been claiming that we have something of value to dispense, and, at times, we have had no takers. For the most part, however, we have now made our market, and our services are very much in demand. But we must become able, through a complete, up-to-date, quickly-retrievable literature, to provide immediate answers. The stock phrases, "That would make an interesting study," or "Further research is necessary" no longer suffice, even though they may be legitimate observations. The applied nature of human engineering demands that every member do his share toward filling the gaps in his field, publishing worthwhile research as quickly as possible. In all likelihood, the necessary body of data is not going to come from the "basic sciences," which are usually concerned with problems of a different order. "Self-reliance" will have to become the password of our profession.

FUTURE TRENDS

Now let us turn to what we might expect in the future. One of the most obvious and most extensive influences on future data collection, storage and retrieval, is going to come from the increased use of electronic computers. For one thing, the fact that computers can integrate data from a number of sources simultaneously or over long periods of time, and derive and predict trends will continue to revolutionize both data-gathering and processing. We should be able to investigate selected variables in a number of widely different situations and still find the communalities that exist. But one of the major problems of engineering psychology is that few systems are static. They must be required to operate under a number of environmental conditions, with multiple operators coordinating their actions in complex ways. Without the use of computers, it becomes virtually impossible to cope with the large number of relevant factors and to examine the complicated interactions among variables which are basic to prediction and control of system performance.

Computers will allow us to have a better picture of the social variables that we mentioned earlier. Because of their complexity, very little emphasis has been put on such variables and their influence on the performance of systems. These factors are often discussed, but we tend to assume that the pressure for successful performance during times of emergency will override the deleterious effects of undesirable social and personal variables. However, with the growth of passive systems in which long-term monitoring is the main task, this assumption may no longer be valid. As computers make the investigation of more complex situations possible, we will be able to look at the personal and social aspects of human operators, and at individual differences. Furthermore, we are going to have to control these variables in order to assure that the system will attain its final goal. We must give up the typical engineering viewpoint that training irons out the individual variations among people, allowing them all to be treated in essentially the same manner. In spite of all that has been said about this in the past ten years, systems are still designed so that the man is added in as a constant switch that may be "turned on" at will. Unfortunately, people are not that stable or predictable: they are influenced by other people, by the surroundings, by their perceptions and cognitions of the past and present, and by their hopes for the future. Failure to recognize these facts has led to rather naive and unrealistic expectations about operator performance in man-machine systems: we seem determined to try to design machine-machine systems. Perhaps computers can provide the tool for investigation of these important variables, and permit us the opportunity to form a more accurate and comprehensive picture of the human beings who comprise a major part of our systems.

Advances in computer technology and cybernetics will lead to the design of flexibility into both training equipment and operational systems. Computers will allow immediate readjustment of such factors as environmental conditions, difficulty level of task, and system feedback sensitivity as a function of system performance from one instant to the next. This is

what constitutes an adaptive system--a flexible, sensitive one responding (as programmed) to both the internal system environment and the external one. For example, as an inexperienced operator improves with practice, his task could be made, automatically, more demanding. If his performance starts to degrade, the difficulty level of the task is automatically adjusted downward. What will this accomplish? It will "overtrain" the operator so that he may retain his skills longer, or be more resistant to stress. He will not be allowed to coast along. With a dull, monitoring kind of task, it will be of great value to be able to modify system input selectively in order to increase the vigilance level of the operator.

With regard to cancelling out individual variations among humans, adaptive systems, although they may seem to do this, actually function to take advantage of individual differences, to concentrate on strengthening one's weak points. For such a system to work best, it will have to be able to make quick and relevant measures of system and human performance, and then feed such data back into the system loop. The measurement problem here is a thorny one--finding meaningful qualitative and quantitative indices of performance, whether one uses behavioral or physiological criteria. Eventually, these sampling data will tell us when to put a new operator into the system because the old one is coming dangerously close to minimal acceptability.

The second general class of future developments centers about methodology, to be discussed more fully in the next chapter. It is becoming clear that the day of the *t*-test is over. Indeed, even the day of the multiple analysis-of-variance may be drawing to a close. More sophisticated mathematical and statistical techniques are to be anticipated as part of the future development of data handling; and, because we are still a young and adaptive profession, one can hope that we will explore these techniques with an open mind, and adopt those that are useful. An example of these new developments in statistical and mathematical techniques is the growth of Bayesian Analysis and Bayesian Decision Theory.

Another aspect of methodology is selection of experimental subjects. We cannot automatically assume that results of stressful experiments as obtained on college sophomores are applicable in a military situation.

We should see in the near future greater sophistication in variable selection, greater willingness to utilize observation of real operational systems, greater understanding of the goals of the system, and willingness to search for those variables that are particularly relevant. In addition, adequate techniques of identifying and isolating relevant variables must be devised rather than relying upon the variables that are classically considered relevant in such situations. There should be a more critical screening of what we call "soft data". We must carefully inspect data resulting from questionnaires in those situations in which we know they are inadequate, inappropriate, or that the results are certain to be distorted as a result of administration. There are occasions when we may unwittingly be guilty of conducting experiments and making decisions which

we can "sell" to management or to the military, but which we would have difficulty in justifying to other engineering psychologists. Fortunately, these data are seldom published, but, by the same token, they represent useless effort and an inexcusable waste of money.

One area in which engineering psychology has played a major role, but in which the contribution is far from fully realized, is that of displays. Optimally, displays should be flexible, adaptive, instantaneously responsive, and interactively synergistic with the human operator. An example of a recently developed, unique-purpose display is a predictor instrument invented by Dr. Charles R. Kelley, and subsequently refined largely with support of the Engineering Psychology Branch of the Office of Naval Research. It provides the operator of a manual control system with information about the predicted future of the variable (e.g., depth or heading) which he is controlling. It does this by means of a special computing device which extrapolates present conditions, e.g., ten seconds in the future. The advantage of such a display can be seen in applying it to submarine depth control, where overshooting is frequent even among experienced operators. With the predictor display, a novice can learn in an amazingly short time to perform this control task as well as or better than highly trained submariners using standard indicators. The difference lies in the fact that when the system is augmented by the predictor instrument, the human controller knows from the start what his system will do under varying conditions because his display contains the needed information; this is so because the dynamics of the vehicle are built into the instrument.

As a concomitant development, investigation of the social and motivational variables surrounding the utilization of information from displays will become more necessary. A great deal of work must be done in devising methods by which we can increase the acceptance of new displays and equipment by the people who must utilize them. Clearly one of the important aspects of human engineering includes finding ways for assuring that new devices will be used, and used properly, by the people for whom they are designed. The Office of Naval Research is presently supporting a study aimed at defining the scope and pinpointing some causes of nonuse and misuse of shipboard gear, as well as developing ways of modifying attitudes towards equipment. Ingenious approaches are needed in this area to unearth valid data, since there may be an understandable reluctance on the part of some to admit to improper utilization of equipment. We must not only make greater use of methods of quantifying subjective values about equipment; we must also become more knowledgeable in multidimensional scaling theory and its techniques. Some might consider this an "encroachment" by the engineering psychologist on the domain of the personality or social psychologist. We prefer to regard it as a legitimate selective borrowing by the engineering psychologist from the "softer" as well as the "harder" disciplines to enlarge his fund of skills and techniques.

Related to the equipment usage problem is that of operational evaluation of systems. Judicious screening of existing methodologies from the

other specialties, together with the development of new custom-made techniques, is necessary to insure valid evaluation. Two pilots must not be allowed to veto the utilization of a complex, expensive piece of hardware merely because they "just don't like it." Pilot opinion can provide valuable information to the engineering psychologist, if it is scientifically sampled, artfully solicited, and rigorously weighted.

The last area about which we would like to make a few predictions is that of data presentation. Clearly, with an increase of engineering psychology literature there will be a need for more journals, some of which will be more specialized journals. Journal articles may have to become shorter and more specialized if the engineering psychologist is expected to keep up.

The number of information storage and retrieval centers being organized attests to an increasing awareness of data presentation problems. Although such services have existed for years in many scientific areas including engineering psychology, these centers have not been utilized efficiently by the scientific community. It is obvious that today an individual cannot conduct a proper literature search, with the vast amount of material available, as well as can an organization with a trained staff and extensive resources. It may become necessary in the future to utilize such information centers before undertaking any research and development program of any consequence. At present, the information centers usually provide a list of references or an annotated bibliography. In the future, tentative solutions should be possible based upon knowledge made available through computer technology which may even make possible, in addition, recommendations regarding needed research.

METHODOLOGY

The goal of engineering psychology in the development of military systems may be stated in terms of man as a contributing component to the total effectiveness of the system in its operational environment.

The methodological problems surrounding the conduct of research in engineering psychology as a part of the systems development process centers around two major questions. The first is "What is man's role within the system?" The second is "What is required to permit him to accomplish this role?" For personalized systems such as a rifle system, although the problem of defining man's role may be relatively simple, the design of a rifle system that will meet stated requirements may be complex. The designer must be alert to postural, visual, and anthropometric considerations as well as weight, impulse, and noise as determiners of effectiveness.

The research and development cycle can be conceptualized as a series of chronological stages:

1. Requirements

2. Concepts

3. Preliminary design

4. Development

5. Test and Evaluation

6. Operations

This outline may appear to define a beginning and an end to the research and development process. In reality, it is circular. Continual attempts are made to increase the capabilities and effectiveness of the system through updating procedures. The operations stage provides a basis for a second generation updating of the system through components research or for radically new systems requirements that eventuate in a new concept.

On a purely objective research level, engineering psychology shares a great deal of communality with applied experimental and task situational parameters. For example, the many research studies on man as a sensor, power generator, controller, decision maker, etc., are representative of the research efforts and have contributed to the development of general human factors principles for the design of equipment and workspace layout. It has also provided the base for the development of the checklists of the past that provide comparisons of man capabilities and machine capabilities.

REQUIREMENTS

Military systems requirements are established on the basis of war gaming studies, operational maneuvers, technological state-of-the art advances in components, and predictions of a potential enemy's capabilities. The requirements may be for a one-copy system such as an air defense early warning system for which there may be no precedent, or for a multiple-copy system such as a tank or a particular type of aircraft. In either case, the requirements are an expression of an operational tactical or strategic need.

Military requirements are both quantitative and qualitative expressions of systems objectives and the environments within which the systems must operate. In addition, constraints in terms of size and weight are imposed and emphasis is placed on operational simplicity and reliability. All have significant implications for engineering psychology, training, maintenance, and logistics.

The first stage of translating military requirements into an understandable framework is the application of the analytic technique of mission profile analysis, which identifies the major phases of the mission and the functions of the different phases. For example, the major mission phases for a ground mobile missile system might be preparation for road march, selection of firing site, emplacement, preparation for firing mission, disemplacement, and preparation for road march.

The phase function analysis also permits an analytic determination of the minimum performance requirements for the various activities required of the function or subfunction. Although the functions and subfunctions need not be specified in terms of man vs machine, this is a logical starting point for the allocation of functions and a first step in defining man's role within the system. The analytic techniques may be extended to include other analyses such as information flow, decision, job, etc.

The analysis at this stage provides a generalized description of the system and provides a model for the collection of relevant information required for the approximate design solutions for the various subsystems, i.e., mobility subsystems, missile subsystems, fire control subsystems, communications subsystems, etc. The information required for such approximate design solutions is generated by considering the state-of-the-art equipment capabilities in addition to the established pool of research data on performance characteristics of the human operator. Where information is non-existent, feasibility research may be required. For example, the mobility subsystem may have the requirement for traversing cross-country terrain at relatively high speeds. Mobility in this sense implies a combination of engine power requirements, suspension system requirements, and driver-crew tolerances to vehicle dynamics in a cross-country terrain environment. To optimize the power and suspension requirements, it is necessary to investigate crew tolerance as a function of g loadings and location of crew members with respect to the center of gravity of the vehicle.

As relevant research information is gathered and synthesized for an approximation of a concept design solution, it may be case in the form of soft or hard mockups. The development and refinement of mockups provide models of the concept system and are used to guide the preliminary design of the system. Final mockups can be evaluated from the standpoint of workspace layout, workflow analysis, time and motion studies, and environmental considerations. Mockups also provide the basis for the preparation of a preliminary task and skill analysis which is used in the training function.

Depending on the degree of sophistication represented, mockups can be used as simulators for the collection of additional information which may be required for the preliminary design phase, or as a verification tool for changes made during preliminary design.

During the preliminary design stage, the engineering psychologist may participate in the design process by providing operational performance requirements information and performing evaluations of component equipment when designed.

The integration of the various subsystem components results in an operational prototype system which is then subjected to engineering test and evaluation procedures in addition to user tests. The distinction between engineering and user tests is that engineering tests are conducted as much as possible without the influence of the human operators; therefore they are a test of engineering specifications, not necessarily operational requirements. The criteria against which these tests are conducted derive from the original military requirements and the ultimate criterion is the effectiveness of the system in meeting all of its tactical mission requirements.

The evaluation of prototypes usually uncovers problems which were not anticipated during the analysis and preliminary design phases and which require a research solution. As an example, consider a problem uncovered during a prototype evaluation of a tank system. For this particular tank, the fire control system required the gunner to place his head in a brow pad which was aligned with the monocular fire control optic. The head alignment had to be maintained through firing to permit the gunner to sense the impact of the round so that in the event of a miss the appropriate correction can be made. Because of the light weight of the vehicle and the recoil stroke of the gun, impact to the head of the gunner forced his head out of the brow pad, thus prevent him from round-sensing. The problem could have been solved experimentally by substituting different brow-pad materials to provide energy absorption; however, ammunition availability for a prototype weapon is in short supply. As an alternative, a mathematical model was constructed of the recoil accelerations of the vehicle and the normal force application of the head and the characteristics of brow-pad material. A solution was obtained with this method which, when tested, proved to be satisfactory.

The acceptance of the prototype marks the end of the research and development cycle and the program then shifts into production engineering. During the production engineering phase, a strong monitoring program is required to assure that the designed-for-effectiveness is maintained. The goal of production engineering is to produce the system as cheaply as possible by the use of standard components and proven production methods. Unfortunately, this often leads to compromises of the original design. For example, a display component may be substituted which will reduce costs but may increase the chance for operational errors.

The deployment of the system to operational units provides the ultimate verification of the total research and development program. It is here that problems relating to readiness, maintainability, and operational effectiveness are uncovered. As a result of field operational problems, additional research may be required to solve the problems either by procedural changes, reallocation of tasks and jobs, or by retrofit.

The accumulation of field operational data provides a partial source of requirements and problems to be considered in the next generation of systems.

The importance of engineering psychology throughout the research and development cycle is a relatively well-accepted fact as witnessed, in part, by its inclusion as a separate category in military requirements documents and industrial contracts. Operational personnel are often the strongest advocates of engineering psychology, for it is they who must achieve the operational goals that have been established for the system.

The success of a scientific discipline is a function of the methods employed in seeking research solutions. The methods of engineering psychology are empirical, being based on analytic techniques and on experiments. The methods range from surveying and interviewing techniques used to investigate operational problems to those of laboratory experimentation and simulation in the investigation of well-defined problem areas.

Research in engineering psychology is not inordinately expensive in terms of money but it is costly in terms of time. With the tremendous emphasis placed on decreasing the time required for developing and producing military systems (currently 5 to 7 years), attempts are being made to express human performance in terms of mathematical models in order that research solutions can be obtained with the aid of computers for at least initial design decisions.

Another area which requires additional attention is methods of test and evaluation. Evaluation periods for prototype equipment are relatively short and thus require accelerated programs. Often realistic conditions cannot be simulated and hence require, in addition to the collection of data, a great deal of logical and intuitive interpretation. In such cases, the operational experience of military personnel is invaluable.

SUMMARY

By way of summary I have set down a few personal observations concerning the state-of-the-art in engineering psychology.

First, the training of engineering psychologists is inadequate with respect to both quality and quantity. Briefly, the qualitative deficiencies involve such matters as too little mathematics, physics, operations analysis, design engineering, and systems engineering. We need better to understand the language of our customer.

Second, it is axiomatic that progress in any field is directly related to the availability of adequate methods. The lack in human engineering is particularly serious in the applications area at the extremes of the systems development cycle. Thus, our contributions are less than they should be at the conceptual and test and evaluation stages of systems development.

Third, much of the available research data in engineering psychology is of very limited value simply because the independent variables are not those that design engineers can manipulate.

Fourth, research is needed especially in the areas of computer-man relationships, automated systems, manufacturing processes, and the effects of combined stressors.

Fifth, while engineering psychology has made significant contributions to the development of military systems, relatively little application has been made to commercial products and systems. The degree to which such application could improve mankind's general relationship with its highly engineered environment is apt to remain a matter for conjecture for some time to come.

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PART VI

MAN-MACHINE PARADIGM IN LARGE INFORMATION PROCESSING SYSTEMS

INTRODUCTION TO PART VI

This session was organized by Dr. Launor F. Carter, Advanced Technology and Research Directorate, Systems Development Corporation (SDC). As framework for the discussions to follow, Dr. Carter describes a large command control system and indicates various methods of characterizing such systems by their physical characteristics, processes being performed, and functions served (Chapter 13). He considers major problems to be resolved through research and development to enhance system responsiveness to user needs.

Dr. Elias H. Porter, also of SDC, develops and illustrates a model designed to lead the systems analyst to consider more fully the dynamics between goal setting, guidance, decision-making, and input patterning for optimizing performance of command control systems (Chapter 14).

Chapter 15 was prepared by a third representative of SDC, Dr. James W. Singleton, who presents a management methodology to assure that the operating man-machine command-control system satisfies the information needs of the using military command. He depicts this methodology as a rational process and spells out the requirements of design control which must be exercised by the user. These requirements center about user-developer-system intercommunication.

CHAPTER 13

LAUNOR F. CARTER

MILITARY INFORMATION PROCESSING SYSTEMS

This paper serves as an introduction to a series of related papers considering the psychological and information processing problems associated with military information processing systems. To set the stage, I will first describe in abbreviated form the new command and control system now being installed for the North American Air Defense Command. Next I will discuss recent progress in command and control research.

THE SYSTEM

The general mission of NORAD is to monitor and defend the aerospace over the North American continent. NORAD must keep track of the status and the identity of all aircraft and space objects which either are, or might be, over the North American area. A number of sensors are required to determine what is in the air or in space; further, the objects which are determined to be in the environment must be identified. Aircraft are identified in terms of their flight plans and known missions. Space objects are identified through information related to their origin, the characteristics of their orbits, and their mission characteristics. Associated with this surveillance and identification function is the responsibility for alerting all military authorities regarding the momentary and predicted defense posture. Finally, in collaboration with higher authority, NORAD has responsibility for initiating appropriate action against any space objects, such as the interception of unknown aircraft.

I will give a general schematized description of the new NORAD control system known as 425-L. While this system description is generally accurate, it necessarily leaves out a number of details and only highlights those portions of interest for our future discussion. I will analyze the system in terms of inputs to it, in terms of the central processing involved, and, finally, in terms of outputs from the system.

INPUTS

The 425-L system is quite different from the systems with which many of us are familiar, in the sense that most of them immediately process data coming in through primary sensors. By contrast, almost all of the data received by NORAD are processed data; that is, the data come from other systems, where they have been preanalyzed. For instance, the SAGE system (Semi-Automatic Ground Environment) and the BUIC system (Back-up Intercept Control) are systems which have radar data feeding into them. Data are analyzed and the status of the analyzed data is then fed into 425-L. Data on space objects are handled similarly. Here again SPADATS (Space Detection Tracking System) and the Navy SPASUR system (Space Surveillance) are tied into various primary sensors. These systems analyze the information coming in, establish orbits, and feed the analyzed information to the NORAD control center. Likewise, the computers of BMEWS (the Ballistic Missile Early Warning System) analyze possible ballistic missile trajectories and feed the analyzed predictions into the NORAD system. The world-wide weather system goes into NORAD, as does the bomb alarm system, and, finally, the intelligence information from a world-wide network. At least six major information processing systems feed into this one system and furnish the information necessary for the NORAD Command to carry out its responsibilities.

CENTRAL PROCESSING

The central data processor in the NORAD system consists of several Philco 212 computers. The requirements for this central processor are different from those frequently found in primary data processing systems or in scientific data processing systems. In NORAD, processed information must be received and stored in various ways so that it can be analyzed and displayed as appropriate. Later, I will have more to say regarding this difficult problem. Some of the information coming in is not automated and consists of written reports or telephone inputs. These need to be translated into a form which can be handled by the central processor.

OUTPUTS

The outputs from such a system are extremely varied and are a product of the way in which command personnel interpret the requirements of the system. One of the requirements is that the system display, on demand, the status of all weapon systems. Likewise, the system must be able to display the status of all sensory systems and communication systems. By "status" I mean the level of operation of the particular system, the probable reliability of data being processed by the system, its readiness to react on command, and its ability to serve the commander under various conditions of degradation. In addition to information regarding the status of systems, a number of dynamic elements must be available on demand, such as the number and probable nature of various unknowns in the aerospace

environment. Similarly, if the BMEWS system shows missiles or other unknown obj ts in its area of surveillance, the most probable impact of such objects must be predicted and displayed. The handling of intelligence information and its interpretation and display is a particularly difficult output problem. Questions of the way in which intelligence information should be displayed, how widely it should be disseminated, and the form of the dissemination are concerns in such a system. Finally, the commander and his staff must be able to communicate with a number of other commands, at a superior, similar, or subordinate level. Not only must the commander be able to communicate, but he must have his information available in such a way that he can share it with other commanders, so that decisions can be made based not only on the interpretation of the NORAD commander, but also on a broader understanding of the data available to him.

THE PRIMACY OF REQUIREMENTS

From this short description of the 425-L system one can sense that the definition of "requirements" constitutes one of the major problems in the design and implementation of such a system. Earlier I described the general mission of the North American Air Defense Command, but this description is in quite general terms, and is not a satisfactory basis on which to design such a system. The nature of the mission must be worked out through a complex set of interactions with the Joint Chiefs of Staff, the collateral commands, particularly SAC, and with the subordinate commands. Usually, the spelling out of the details of a mission such as this, although arduously worked on, is never sufficiently detailed to serve as a basis for defining requirements for a command and control system; indeed, the requirements are in a constant state of flux, since the mission and resources of other parts of the military in which the system is embedded are also in a state of flux. The designers of an information processing system based on such a general and yet changing mission statement are faced with the major dilemma in command and control systems--the problem of how to participate with the user in the detailed definition of his requirements. Too frequently the user has an understanding of his general need for a command and control system but has not adequately specified the details. Often, indeed, he cannot do so because his familiarity with the technical capabilities and limitations of information processing equipment is at a general level rather than at the state of specificity required. I will not labor this point further because Dr. Singleton's paper will consider this matter in greater detail.

SOME CHARACTERISTICS OF LARGE INFORMATION PROCESSING SYSTEMS

I will now discuss some of the characteristics of information processing systems in terms of inputs, the central processor, and outputs. One could characterize these systems in many other ways, and, indeed,

Dr. Porter will show that this particular model is too superficial to catch some of the subtleties of interaction and feedback. Nevertheless, it gives a good framework for further consideration of these complex information processors.

SYSTEM INPUTS

On the input side, it is fairly obvious that many different kinds of sensory data will come into the system. These data may consist of raw radar data, infrared information, previously processed data which arrive in terms of equations or tracks, written information which comes in as natural text, categorized tabular information or verbal information coming over the usual communication channels. In designing a system such as 425-L, many decisions are required in specifying the character of the input information. As an instance, consider the question of what the commander of NORAD needs to know about the height of unidentified aircraft. At one time it was thought that he should know the height as accurately as the aircraft controller at a direction center. More recently, there has been a feeling that it is sufficient for him to know whether incoming aircraft are in one of two broad categories--high flying and very low flying--since this information gives him the necessary insight into the nature of the overall pattern of attack. It could be argued that he does not need to have any height information--that, indeed, there is not a great deal he can do about it, and that he should leave this kind of concern to his subordinate commanders. Or, in the tracking of space objects, how accurately should the orbit of such objects be determined? Is it adequate to have such orbits accurate within a few miles for any given predicted time, or must the accuracy be much greater? The answer depends, of course, upon need. If the only need is identification, then rather gross orbits may be adequate. On the other hand, if the objective is interception, then the orbit must be known with great accuracy. The point of these examples is that detailed decisions must be made which are satisfactory to the commander and his staff. The most detailed and extensive interaction between the system designer and the user is required.

THE CENTRAL PROCESSOR

One might think that once a decision has been made to have a large command and control system, the question of the kind of central processor would be fairly easy to determine, but this is as difficult a problem as that of determining the various sensor requirements. Fundamental questions must be answered: In what form and amount is the data available to the central processor? That is, in what form will the data be stored and how will the data processor process these stored data? Must the data be instantaneously available to the central processor or can fairly long delays be tolerated? Will the users of the central processor need very fast responses to their requests? Will each of the users be in contact with the central processor at all times, as in the case of time-sharing

or must they wait their turn in some kind of cycle, such as is the case in the SAGE system? Questions such as these will determine how large the central processor memory must be, how much peripheral memory must be associated with the computer, how the peripheral memory will be divided in terms of speed and functions, and how it will communicate with the central processor. All these considerations are highly technical, and yet their determination is very much a function of the human interaction with the central processor and the kinds of requirements imposed on the system by the user and the designer.

SYSTEM OUTPUTS

Finally, the requirements will determine the kind of outputs. Whether the outputs should be on consoles or simply printed depends on the nature of the decisions required and the ability of the command to state its true needs. Generally speaking, consoles available for displaying the computer-based information are well designed from a human engineering standpoint. The major problem is that of determining what kinds of information should be displayed on the consoles. The same sort of statement can be made with regard to almost all our current output techniques, whether electronic or printed. The ability to state adequate display solutions to commanders' requirements is an art which we as yet little understand. Similarly, the problem of immediate dynamic interaction with the computer depends on a technology which is coming nearer and nearer to our grasp, but how the commander and his staff will use this capability is something that needs further exploration.

SOME RESEARCH NEEDED TO IMPROVE LARGE INFORMATION PROCESSING SYSTEMS

I would like to indicate a list of problems which have been implied by the above discussion and to make a few statements about the research and development needed to make these systems truly responsive to the users' needs.

1. New hardware needs to be developed--particularly larger and cheaper memories. Generally, human factors personnel will not directly contribute to the details of hardware development, but they will be concerned with the specification of the requirements of new hardware--specifications regarding the proper organizational design of central processors to permit efficient and easy use, specifications regarding display equipment to allow flexibility and meaningful display of information.

2. New computer programming systems and languages are needed. These systems must retain the power of large data processors, yet allow close dynamic relations between the user and the equipment. We must get away from fixed, inflexible, long-change-time programming systems.

3. The formatting and structuring of data bases are becoming more and more important. Data bases containing well-defined, orderly, static, unitary information can be handled expeditiously now, but data are usually not "naturally" available in this fashion. We must develop the ability to handle data arriving in an unordered fashion from numerous sources of different quality and class. We need to be able to manipulate such data easily so that the output is orderly and easily interpreted. Increasingly, certain kinds of systems may be functionally decentralized in order to improve their resistance to degradation because of destruction, or for other reasons. It will therefore be important to learn how to organize and disseminate information to be most useful to these multi-center arrangements.

4. Another problem centers around the handling of natural language. Much military information is not in tables or radar returns, but rather in written reports, manuals, instructions, directives and spoken comments. The computer should be able to process such information. It should be easy to store it, to manipulate it, to find its implications, to compare different parts, to retrieve relevant pieces--in short, to provide an auxiliary brain for the user.

5. We can now produce large, million-instruction programming systems, but at a high price in time and cost. Methods for the near automatic production of machine code are needed. It should be possible for the military user to state his requirements and then to have the requirements translated into machine instructions almost immediately. To do this calls for many new techniques. New compiler and translator methods are needed. The ability to check code automatically through heuristic methods needs to be exploited. New methods of aggregating segments of prepackaged code can be developed.

6. The military user's ability to state requirements poses a problem. While he knows the general requirements, formulation of the specific requirements is difficult. Today, there is a long delay between the statement of specific requirements and feedback so that the user can determine whether the specific requirements really satisfy the general requirement. Techniques to help the user translate from the general to the specific can be developed. Such techniques should allow the user to "experiment" easily with the display requirements, with the way in which data are aggregated, with various comparisons made automatically, with the routing of information. In short, there should be an automated information processing system design technology.

7. Even if all the above were accomplished, the most effective use of large information processing systems depends on the organization in which they are embedded. The development of good organizational structure to exploit the potential of modern data processing capability hinges on the ability to organize properly the human element or personnel subsystem. Different methods of hierarchicial and vertical structuring and information passing markedly affect system performances. Some general principles

are being developed, and should be extended. Of great importance is the development of effective methods of training and evaluation of system performance. The long successful history of SDC's System Training Program demonstrates this, but the principles making such programs effective are not yet well understood, nor has the ability to transfer such programs from one system to another been adequately developed.

8. It has often been said that the computer should not be substituted for the human decision maker. Such statements are at too gross a level; certainly the computer can compare two long series of numbers and "decide" whether they are the same or different better than can a human, just as the human makes qualitative decisions better than can the computer. The real problem is not which can make the better judgments but rather to determine methods to enable the human, through use of the computer, to maximize the quality of his decisions. Studies of methods to maximize the coupling, to promote "closeness," are needed.

In the first half of this paper I have briefly described a large information processing system, some of the technical characteristics of such systems have been noted, and a list of needed research and development has been given.

RECENT PROGRESS IN COMMAND AND CONTROL RESEARCH

NEW MACHINE CAPABILITIES

In spite of some thought to the contrary, I am still of the opinion that large general computers need to be employed as the central data and information processor of command and control systems. Recently we have seen the announcement of very large and capable new equipment configurations -- such systems as the IBM 360/92, CDC 6600 and GE 635. These new central computers are capable of great flexibility in terms of the amount and kind of peripheral equipment that can be used with them. With proper software almost any amount of high speed and bulk disc storage may be used to hold static or dynamic data inputs for a command and control system. Similarly, the kinds and number of displays that may be individually controlled have become very large. Along with this greatly increased capacity have come much flexibility and ease in use of the equipment.

The absolute cost of these systems is large--five to ten million dollars--depending on the particular configuration. Nevertheless, the cost per operation is relatively low. The cost effectiveness and efficiency of modern computers have been doubling every three years for the last fifteen years. The relative cost of performing several basic operations on some of the older and on the new series of machines is shown below from a paper by Clayton et al, 1964. The increase in efficiency for these large machines is spectacular. At the same time small and medium

size machines have been improved greatly in cost effectiveness and capability.

Machine	Instructions/ Second	Cost/ Second	Cost/ 10,000 Instructions	Performance-Cost Ratio	Cost to Compile 100 FORTRAN Statements
704	40,000	$.04	$.01	1	$16.80
7090	150,000	.09	.006	1.6	1.40
3600	400,000	.08	.002	5	.50
6600	3,000,000	.16	.0005	20	.10

Time-Sharing. By now computer time-sharing has become quite well-known. As Samuel (1965) points out, computer time-sharing is an old practice dating back to the early Bell Telephone Laboratories relay computers. The SAGE programming system was a time-sharing system but of a somewhat different type than the current systems. Modern time-sharing systems are designed to give users full use of the range of capacities of the computer system. The only exception is that the amount of time one person controls these capabilities is limited by the other near simultaneous users of the system. The MAC system at M.I.T. and the SDC time-sharing system are probably the two best-known and advanced systems now in regular use. (Samuels, 1965 and Schwartz, 1964). In these systems the user is able to call on all of the capababilities of the equipment configuration, he is able to express his needs in several of the standard procedure-oriented programming languages, he has available the capacity for storing large amounts of data for transfer to high-speed storage and manipulation, and he has use of a variety of input-output devices such as teletypewriters, CRT consoles, and graphic tablets. Through these and other devices he is able to insert his own programs into the computer or use already-existing sub-routines in the manipulation of data which he has already stored or is dynamically inserting into the system.

This new flexible capability has only recently been developed for regular use. As far as is known, it has not yet been applied in any operational command and control system, although its potentials seem obvious--a point we will return to shortly.

Data Base Storage and Manipulations. All command and control systems make use of data bases. A commander must make decisions or give directions in terms of the information available to him--usually from information which has been previously gathered or from data which is arriving and being analyzed in real time. In the past, computer programming systems have been relatively rigid in their handling of data. The format of the data and its processing were fixed by the design of the programming system. As systems

were exercised it often became apparent that the data was not well organized or easily retrievable and considerable reprogramming would have to be done to meet newly expressed requirements. To alleviate this problem both SDC and MITRE have been developing general purpose data base storage and manipulation systems. The MITRE program is known as ADAM, and SDC's is called LUCID. These systems are being designed to operate as a part of a time-sharing system. In the case of LUCID a system user is able to describe his data and its organization to the computer system as he enters the data. He is also able to specify the processing functions to be performed on the data and the way in which he would like to retrieve all or part of the raw or processed data. What is critical is that the operator is able to specify data forms and operations at the time the data are being entered. By using a near natural language set of instructions he can build a data base description and specify a set of manipulation routines as the need arises. If his first efforts do not produce information in the form desired the user can simply erase the previous instructions and develop a new set of instructions. When this system is fully developed it will give command personnel truly flexible control over the data which forms the basis for their decisions.

General Purpose Display. As a part of the SDC time-sharing system we are also developing a general purpose display capability. When finished we will have a capability through which the user can build almost any display, as he wants it. In the past a programmer had to write into a computer program a routine which would produce the required display. With this new system a user who is not trained in programming will be able to generate almost any desired display format for the data base stored in the machine. He will be able to apply various transformations or operations on the data and have the results displayed as he desires. This can be done at any time by system users such as military command personnel.

The experimental general purpose display station consists of an CRT display, a RAND tablet, a light pen, a teletypewriter, and a set of special switches which control various computer operations associated with the display process. The operator is then shown a bar graph plotted on a CRT with seven variables shown as a percent of the total. The determination of percentages from raw data, the generation of the line segments, and the labeling are accomplished by the computer as the operator sits at the station and tells the machine his wishes. As he desires, he could change the number of variables, the data base, the format, or any other display characteristic. No special programming would be required.

A command and control system having a time-sharing system with the capability of manipulating its data base and displaying the results in terms of the changing demands of command personnel does not yet exist. But already such a capability is available for laboratory demonstration. When such systems are in operation military personnel will have the capability to query their information sources and display the results, as long as the data is numerical or is subject to categorization.

WAS THE CONSTITUTION , OLD IRONSIDES , OF WOOD OR IRON ?

SCORE= 0.54228281 (moderately relevant)

++ ONE OF THE MOST FAMOUS SHIPS OF THE +UNITED +STATES +NAVY WAS NICKNAMED '' <u>+OLD +IRONSIDES</u> '' . IT WAS NAMED THE '' <u>+CONSTITUTION</u> '' WHEN IT WAS BUILT . IT WAS A FRIGATE - A SAILING VESSEL .

WHAT NOW? (NONE-NEXT-MORE) NEXT

SCORE= 0.51564109 (sharply relevant)

++ THE '' <u>+CONSTITUTION</u> '' WAS LAUNCHED IN L797 . IT WAS MADE OF WOOD AND HAD 44 GUNS .

WHAT NOW? (NONE-NEXT-MORE) NONE

HOW MANY METEORS STRIKE THE EARTH'S ATMOSPHERE EACH DAY ?

SCORE= 0.64671176 (moderately relevant)

++ THE INSTRUMENTS IN THE SATELLITE WOULD SEND DOWN MESSAGES BY RADIO TO STATIONS ON THE <u>EARTH</u> . THE MESSAGES WOULD BE ABOUT SUCH THINGS AS COSMIC RAYS , TEMPERATURE , THE THINNESS OF THE <u>ATMOSPHERE</u> , SUNLIGHT , AND <u>METEORS</u> AND METEORITES .

WHAT NOW? (NONE-NEXT-MORE) NEXT

SCORE= 0.53134202 (sharply relevant)

++ IN THE SOLAR SYSTEM THERE ARE ALSO HUNDREDS OF COMETS , THE VERY STRANGE HEAVENLY BODIES THAT HAVE TAILS STREAMING OUT FROM THEM . THERE ARE , TOO , GREAT SWARMS OF <u>METEORS</u> . <u>METEORS</u> ARE PIECES OF METAL OR ROCK , MOST OF THEM NO BIGGER THAN GRAINS OF SAND . <u>MANY</u> <u>METEORS</u> ARE PULLED TO THE <u>EARTH</u> <u>EACH</u> <u>DAY</u> . THEY BECOME WHITE HOT WHEN THEY FALL THROUGH THE AIR . THE SMALL ONES ARE CALLED SHOOTING STARS . THE LARGEST OF THEM ARE KNOWN AS FIREBALLS .

WHAT TREE IS CUT AT NIGHT ?

SCORE= 0.75782752 (irrelevant)

++ THE FIRST <u>NIGHT</u> SHE TOLD THE SULTAN AN INTERESTING STORY . SHE PROMISED TO TELL HIM ANOTHER THE NEXT <u>NIGHT</u> . HE DECIDED TO LET HER LIVE ONE MORE DAY . DAY AFTER DAY HE PUT OFF KILLING HER BECAUSE HE WANTED TO HEAR THE NEXT STORY . FOR A THOUSAND AND ONE <u>NIGHTS</u> SHE TOLD ONE STORY EVERY NIGHT . BY THAT TIME THE SULTAN WAS SO MUCH IN LOVE WITH HER THAT HE WOULD NOT HAVE <u>CUT</u> OFF HER HEAD FOR ANYTHING .

Examples of Sharply Relevant, Moderately Relevant, and Irrelevant Answers from Protosynthex

Natural Language Manipulation. Even the manipulation and analysis of natural language is coming near to accomplishment by modern programming and analysis techniques. At SDC we have developed a natural language analysis program known as SYNTHEX. One of the goals of SYNTHEX is to achieve a capability which will enable a computer to answer natural language questions from unprocessed natural language text. Simmons (1965) has recently reviewed the state-of-the-art in this area. He cites several systems which have some capability, and he also analyzes the problems which must be solved to achieve more capability.

SYNTHEX is currently one of the more advanced systems, the material on page 240 illustrates some of the kinds of questions it can answer. In these examples the computer data base is the running text of the Golden Book Encyclopedia--some 300,000 words of text. Already a somewhat less general form of SYNTHEX is being used experimentally by the Los Angeles Police Department to help analyze unprocessed crime reports (Issacs and Herrmann, 1965).

What More is Needed? Many command and control systems have been criticized for their inadequacies. Major criticisms are:

1. They are too rigid. The display and data processing routines cannot be changed without extensive reprogramming.

2. Only highly trained technical personnel can operate the systems or change them, and few military personnel are trained in this area.

3. It takes too long to build them--by the time they are operational, the requirements have changed, and they must be largely reprogrammed.

4. The costs of redesigning programs and maintaining and installing them are too high. Often the initial programming system cost equals the cost of the hardware and is a continuing expense.

It should be apparent that the experimental systems described above are being developed in an attempt to meet these criticisms. It now appears that all of the criticisms except cost will be overcome soon. These new systems are flexible, their operation does not require highly trained technicians, it does not take long to build the desired operational routines and displays once the basic programming systems have been developed. But the building of these advanced programming systems is expensive and can only be done by highly experienced experts. So far large and expensive computers are required to achieve the capabilities described, and though we are working on versions of these systems for smaller machines, they will have a reduced capability.

Even if all these developments are successful, the command and control problem still will not be adequately solved. The basic problem is that the requirements for command and control systems are both too complex and too

poorly defined. The commander wants to control each soldier personally, every airplane, each tank. He wants to know the characteristics of each airfield, each enemy bunker, each Chinese junk. To do this takes a great deal of data collection and processing. The amount of communications is staggering. As the scale of conflict increases it becomes impossible for the highest level to be intimately involved and the locus of detailed command and control shifts down the chain of command. As this shift takes place the emphasis of command and control systems also changes, particularly regarding the detail of information that can be collected and the amount that is useful at the several levels of command.

In this half of the paper I have emphasized the new flexibilities being developed in command and control systems. These new capabilities h have resulted from the work of professional information processing system designers and some psychologists who are also knowledgeable in programming. It appears that the problem is now changing to one of better understanding the nature of the command and control problem at the various echelons of command. It seems apparent that this is a job which can best be done by teams of researchers in which psychologists who have had long experience living with military command and control problems will play a prominent part. I would like to see a study program initiated which would intensively investigate the real needs of command and control; on such a team I would have military officers who have had operational command experience, system engineers, computer and communications specialists, and psychologists who have had experience in military command and control settings.

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CHAPTER 14

ELIAS H. PORTER

A PARADIGM FOR SYSTEM ANALYSIS OF COMMAND AND CONTROL FUNCTIONS

For many years, thought in American psychology was dominated by the Stimulus-Response paradigm, S — R. The paradigm suggests, in effect, that the proper object of study is not the structure of the organism accepting the stimulus and emitting the response, but rather the patterning of the stimulus world and its mating to a specified response. To be sure, the patterning of the stimulus world and mating of stimulus to response are important, but they are only part of the total picture.

It is my intention in this paper to introduce a paradigm which has been conceived in the course of system analysis activities, which is much more complicated than the S — R band paradigm and which, it seems to me, is a better paradigm of behavior because it represents so many more behavioral functions. I shall present the evolution of the paradigm, illustrate its usefulness in system analysis, and then make a sketchy initial effort to relate the paradigm to individual behavior.

The introduction of the Stimulus → Organism → Response paradigm, S — O — R, began to invite conjecture as to the inner workings of the organism bounded by the skin. The nature of the "black box" became a legitimate area for study. Norbert Wiener pointed out that many black boxes have in common a structural characteristic called a feedback loop (see figure 1). Responses are compared against a criterion, or against criteria, to generate an error signal which modifies subsequent responses.

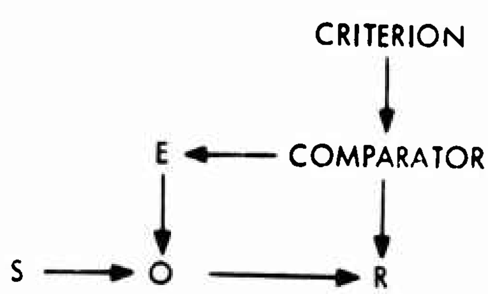

Figure 1.

Sydney and Beatrice Rome have pointed out that if a response is to be compared against a criterion, the criterion must have been in existence before the response. From where do these criteria arise? They arise because organisms and organizations have purpose (see Figure 2).

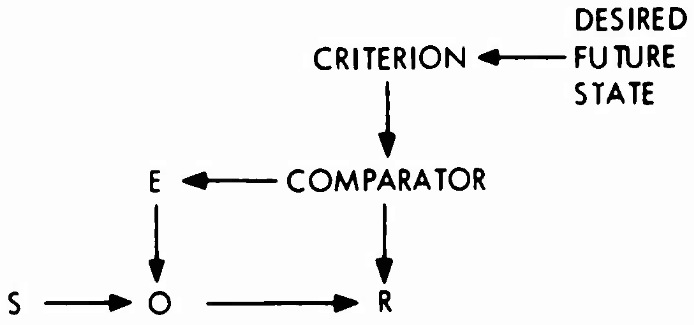

Figure 2.

Alfred North Whitehead is reported to have said, "Even the Behaviorists meet for the purpose of arguing that there is no purpose." When we view a command and control system, we have no trouble in seeing that it has a very clear purpose which had better be taken into account when we analyze the system.

A further characteristic of many systems is that their responses to the stimulus world produce consequences which in turn modify that stimulus world. (see figure 3). This diagram is quite adequate for the representation of simple mechanical systems such as the thermostat-furnace system

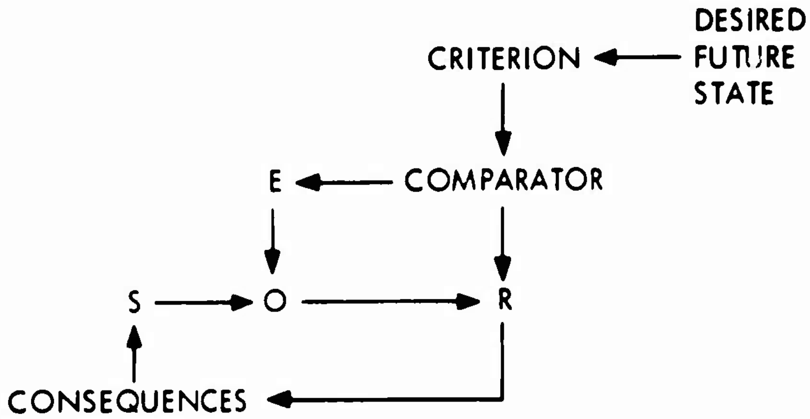

Figure 3.

whose purpose is to maintain a certain range of temperatures. The upper and lower temperature limits built into the device represent the criteria. The rising and falling column of mercury represents the comparator. The error signal is the electrical signal sent to the furnace turning it on or off. The furnace is the organism and its response is the production of

heat or the cessation of production of heat; this response has consequences for the temperature of the room, the stimulus which activates the system. On the other hand, when we view a command-control system for an air defense division, the model leaves much to be desired.

Fortunately, we are able to look inside the skin of a command-control system to see that several functions are being performed by what is represented in the diagram as one function, "O" for organism. The nature of the world of events penetrates the skin of the command-control system (dotted line) through sensors connected to a number of mediating agencies. From the sensors, the data are processed and stored in memory; decisions are selected from among many alternatives; guidance is provided according to fixed or changing goals; and outputs are made to the mediating agencies which produce consequences and, in turn, alter the nature of the world of events.

This paradigm, as presented in figure 4, is like a map--it shows things in relation to each other. And like any map, it could not be drawn until the terrain had been explored. What is particularly useful about this map, being a map of the functional relationships found in most systems, is that it helps us to see commonalities in the operations of quite different sorts of systems and it serves to alert the system designer to the possibilities and probabilities of dynamic interactions between component functions. One very common error in system design, for example, is the notion that the more data that are made available to the decision maker, the more informed he will be. Experience has shown that this is not necessarily so, as I shall soon illustrate.

Let us see how this model translates to an actual air defense command-control system (see figure 5). Stimulus inputs would consist of telephoned reports from radar stations, teletype and telephone messages from higher headquarters, and messages from air fields, weather stations, air traffic control facilities, and other military agencies. There must be sensors (usually human operators) to receive these messages into the command-control system. The messages must be processed (usually by human operators), displays updated, and units of information correlated and routed in such a way that decision makers can make those decisions best judged to implement the goals or missions of the commander. In both the processing functions and the decision-making functions, operators have access to such memories as status boards detailing information on fighter status, weather status, flights under surveillance, and state of alert. More often than not these memories are public memories, open to all to see, and are outputting information as well as receiving inputs through being updated.

In the processing functions and decision-making functions, activities are controlled by a guidance function; there are standard operating procedures, emergency procedures, and policy guides. How information is to be processed, what decisions are to be made, and when they are to be implemented are not so simple as the signal to turn the furnace on or off. When unexpected situations arise, for which no suitable guidance exists,

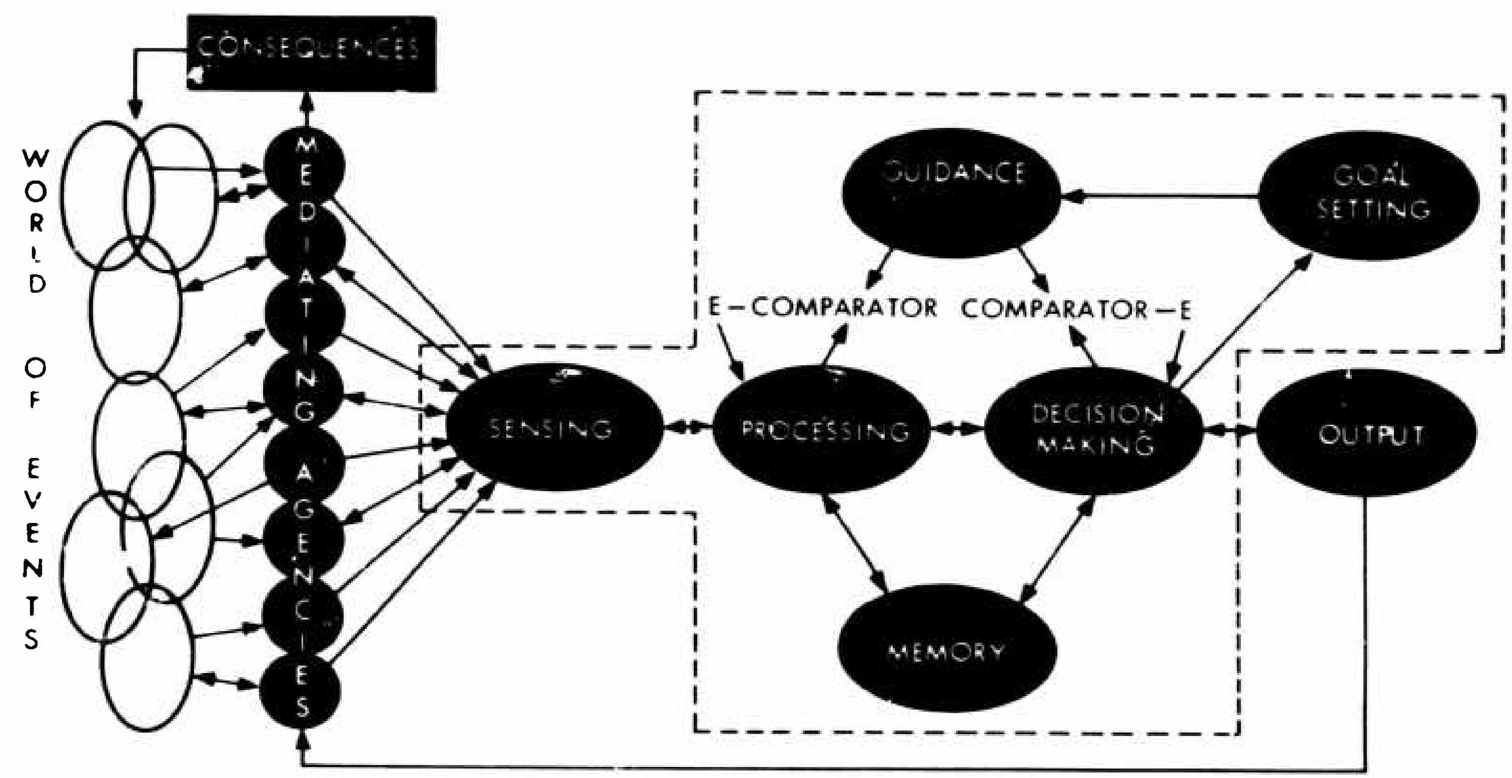
CONSEQUENCES
WORLD OF EVENTS
MEDIATING AGENCIES
SENSING
PROCESSING
DECISION MAKING
OUTPUT
GUIDANCE
GOAL SETTING
MEMORY
E—COMPARATOR
COMPARATOR—E

Figure 4

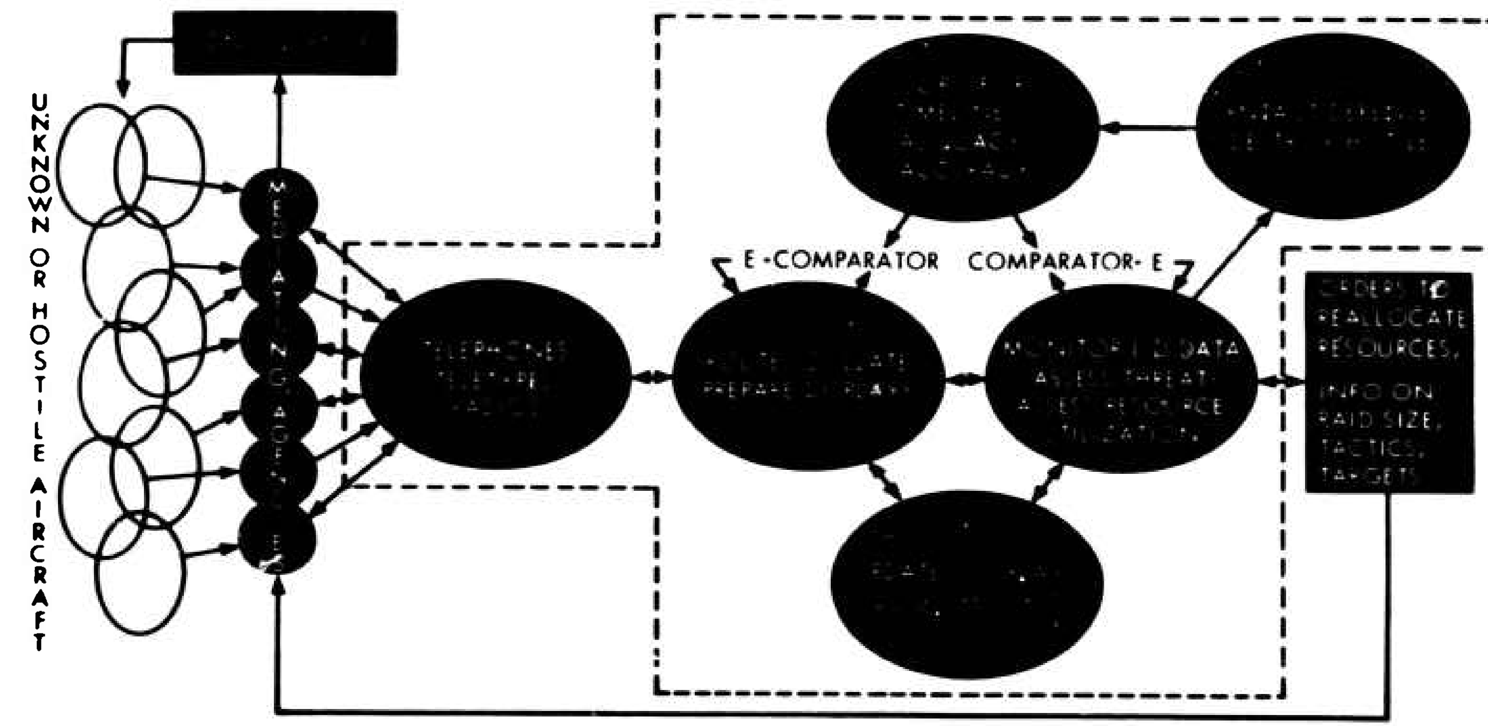
UNKNOWN OR HOSTILE AIRCRAFT
E-COMPARATOR
COMPARATOR- E
ORDERS TO REALLOCATE RESOURCES,
INFO ON RAID SIZE, TACTICS, TARGETS

Figure 5.

decision makers may resort directly to goal-setting functions to provide guidance. In both the processing and decision-making activities we see a constant, ongoing comparison of the pattern of the information format with a range of guidance criteria before the system makes its response or output. The signal to turn on the furnace has the consequence of producing heat, which directly changes the temperature of the room, which in turn is sensed by the thermostat heat-sensing device; the responses or outputs of the command-control system are mediating agencies, which in turn take actions that have consequences which ultimately modify the event world and which, when sensed and processed, may result in new decisions.

Experience has taught us that in system analysis of a command-control system we must understand the following very clearly: (1) the system's mission or goal, (2) the criteria by which decisions are to be made, (3) the decision-making activities which will permit the goal to be achieved; and (4) what patterning of inputs makes it possible to engage in effective decision making. These functions are dynamically interrelated. Not understanding this can lead to trouble.

To illustrate the importance of the dynamic interrelatedness of these functions, let us consider a study conducted in a northerly air defense division headquarters during the days of manual operation, that is, before the functions were automated. The goals of the commander were clear; he was to keep his defenses intact and to destroy as many enemy aircraft as possible. It was recognized that in the event of large-scale raids he could only hope to destroy as many enemy aircraft as possible, that it would be impossible to destroy them all. As is so often true in systems designed on the assumption that the more data displayed to the decision maker the more informed he will be, the data displays available to the commander were such as to give <u>detailed data</u> on <u>each</u> event under surveillance by the mediating agencies. For purposes of exposition, I shall take liberties with the details of the study and present only the essence of what is relevant to our purpose here.

Three air defense sectors reported into the division headquarters for which the commander had responsibility (see figure 6). A script had been prepared for each sector detailing a realistically heavy-load battle situation. The scripts listed, minute by minute for a two-hour period, exactly what the radar scope readers would have seen on their scopes had the battle situation been real. Using the script inputs instead of scope inputs, the system operated according to established procedures. At division headquarters the commander sat before the displays of data as they were posted. Inasmuch as the battle situation was synthetic, it was possible for a team of observers to know exactly what the commander's displays would look like, minute by minute, if all of the data were being processed and posted in a timely manner. The measures taken by the observer team indicated that only about 55% of the displayed data were timely, that is, only about 55% of the data were posted by the time the commander had to make his decisions. The remaining data were still being processed.

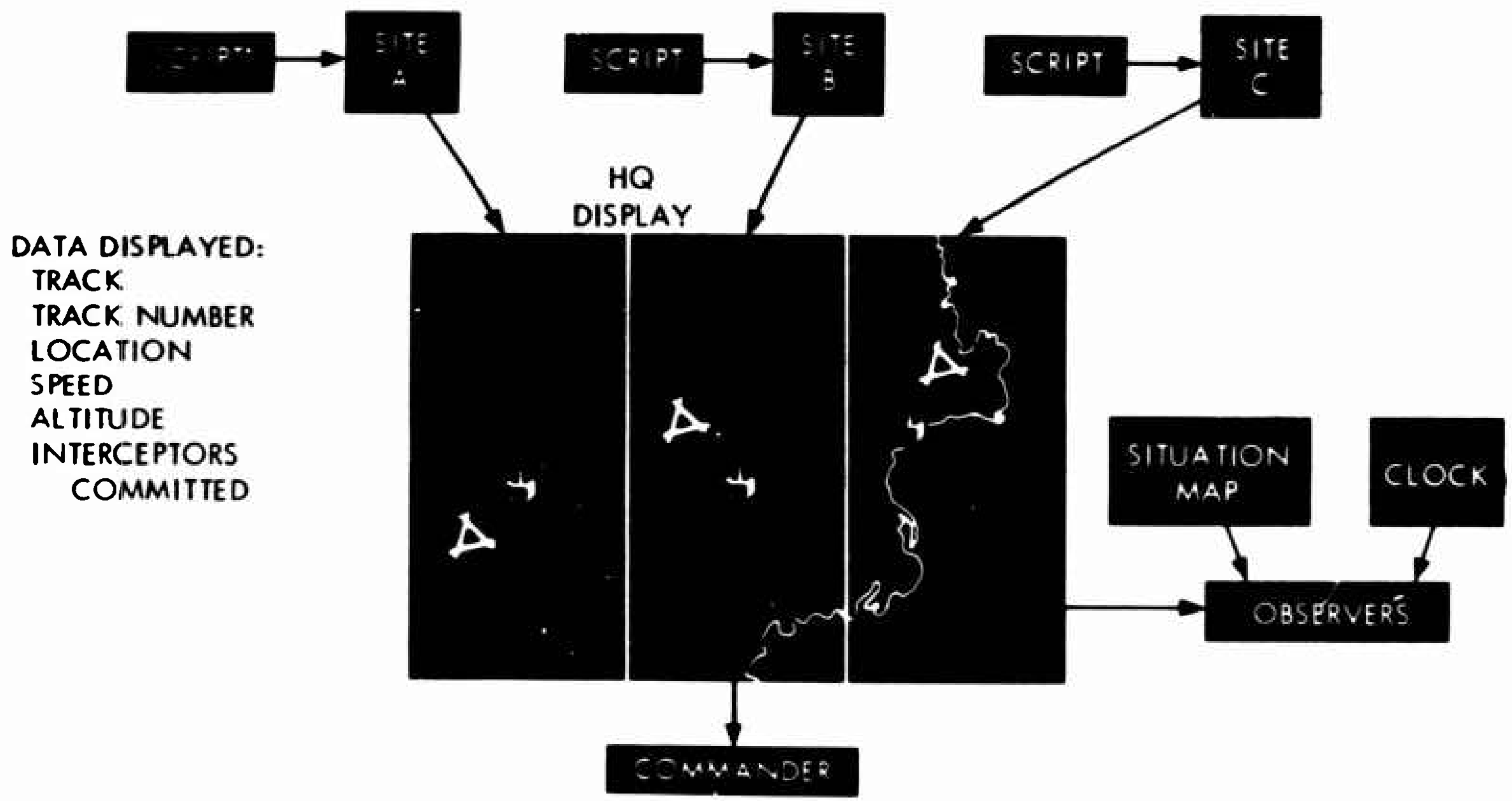
SITE A
SCRIPT
SITE B
SCRIPT
SITE C
HQ DISPLAY
DATA DISPLAYED:
TRACK
TRACK NUMBER
LOCATION
SPEED
ALTITUDE
INTERCEPTORS COMMITTED
SITUATION MAP
CLOCK
OBSERVERS
COMMANDER

Figure 6

Moreover, at the end of the two-hour problem period, the commander reported feeling overwhelmed by the mass of data. Note that I say data, not information. Displayed as they were, the data were not very informative.

The next step in the study is illustrated in figure 7. Each sector was divided into subsectors. Data were aggregated at each sector and were reported to headquarters in total sums, for each subsector; that is, the total number of tracks under surveillance in each subsector was reported, and the total number of interceptors committed in each subsector was reported. The procedures also permitted altitude and speed to be reported. If the commander wanted fine-grain data, he could telephone the sector and obtain it. Under these reporting conditions the observers determined that over 95% of the data displayed to the commander were timely. The new procedures were rapidly refined and adopted. It was clear that how the world of events was mapped in the memory at the command-control system markedly affected the ability of the system to achieve its mission.

The mapping of information for organization leaders, as such, is not new. The profit-and-loss statement has been with us for years. Annual reports with statistical summaries are commonplace. What is new is the recognition that just how the information inputs are mapped or patterned may play a vital role in helping or hindering the organization leader in his task of making decisions intended to achieve the organization's mission or goal, especially in real-time, on-line information-processing systems. The data displayed in memory to the organization leader are his maps of the operational terrain or world of events; and we know that maps must differ according to the purposes they serve.

The final modification of the paradigm points up yet a different set of system design applications (see figure 8). Just as situation displays are memories, so, in fact, are SOP's and policy and procedure guides. A situation display is a memory of the world of events; the guides are a memory of what to do about those events. In most organizations the guidance memory is in some form of storage; that is, it is stored in the bound pages of procedure guides and manuals. We know that when the world of events can be properly mapped in a visible mode, the organization operates more effectively. The challenge then faces the system designer as to how to map, how to make visible, how to make public the guidance functions--and especially challenging is the giving of visibility to organizational goals and to the steps for reaching those goals.

The making visible of SOP's is not really new. The pilot's preflight check list is one such display. Consoles often have alerting devices for what to do next, or to signal an illegal action. "No Smoking" signs give us guidance. One is not faced with the formidable, if not impossible, task of learning the traffic regulations for an area: traffic signs provide readily accessible and timely guidance. Nor is the making visible of goals really new. The Red Cross "thermometer" shows the goal of the fund-raising drive and the proximity of attainment of the goal. Sales managers for years have used charts and other visual displays for setting forth the goals of a sales campaign.

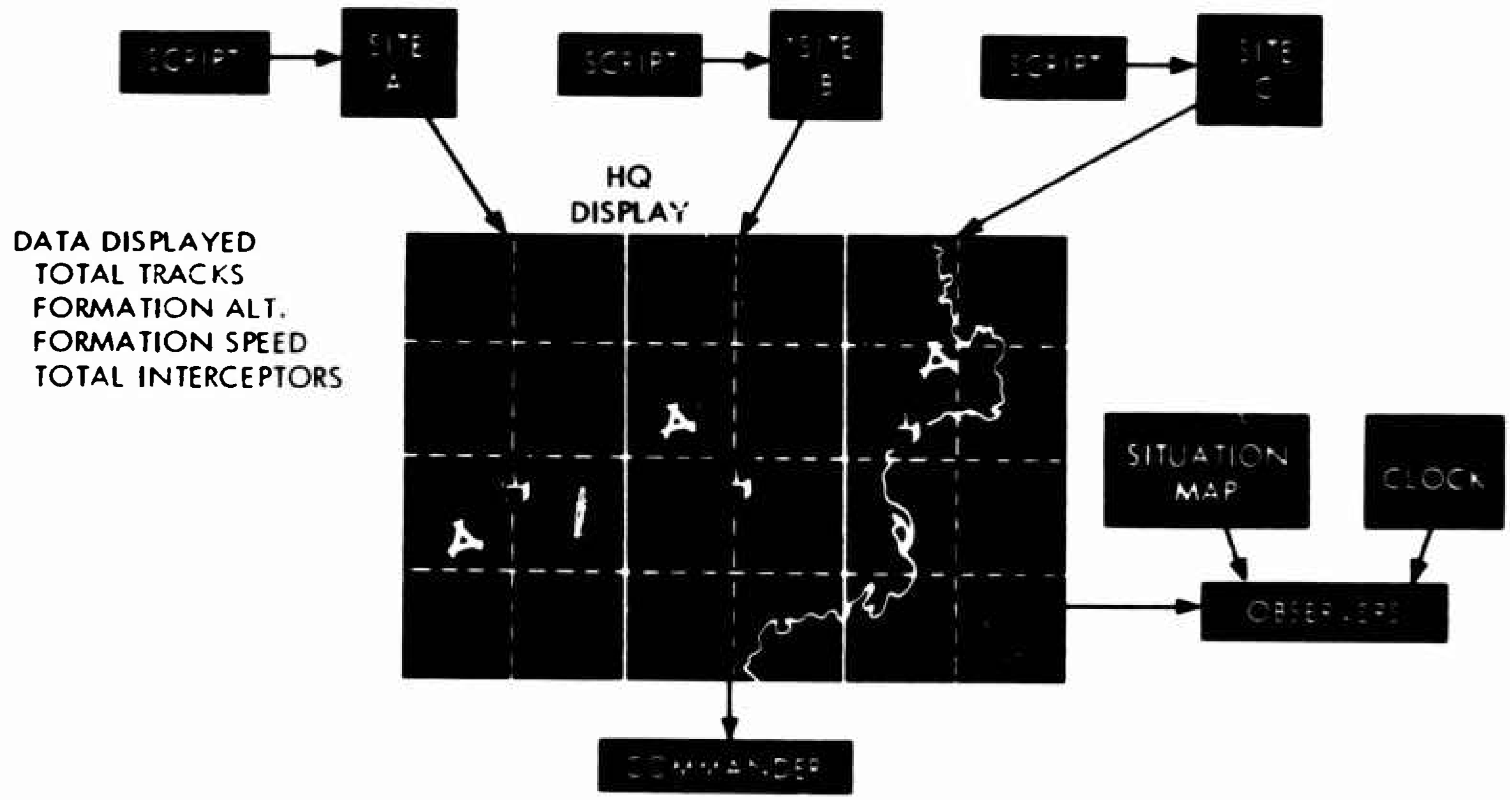
DATA DISPLAYED
TOTAL TRACKS
FORMATION ALT.
FORMATION SPEED
TOTAL INTERCEPTORS
SCRIPT
SITE A
SCRIPT
SITE B
SCRIPT
SITE C
HQ DISPLAY
SITUATION MAP
CLOCK
OBSERVERS
COMMANDER

Figure 7

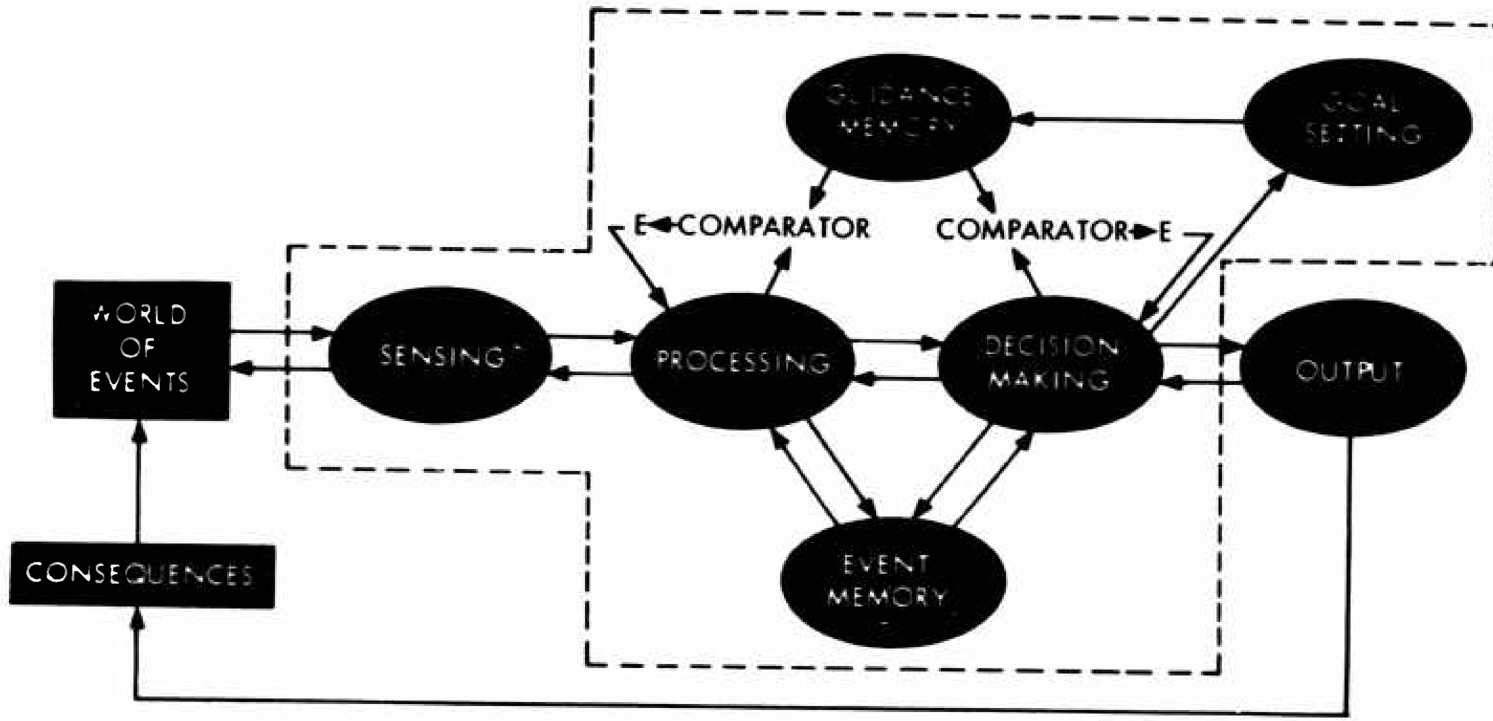
WORLD OF EVENTS
CONSEQUENCES
SENSING
PROCESSING
DECISION MAKING
OUTPUT
GUIDANCE MEMORY
GOAL SETTING
EVENT MEMORY
E COMPARATOR
COMPARATOR E

Figure 8

What is new is the clear recognition of the advantages to be gained by making SOP's, plans, and goals visible. Probably the most significant jump forward in the making visible of plans was the development of the PERT procedure. Quite aside from the time and cost control features of PERT and quite aside from the fact that it forces a project to be planned from beginning to end before its start, there is the important benefit that the plan is visible. Everyone associated with the project can see what the plan is, step by step, from outset to conclusion. And everyone associated with the project can see what consequences their behavior will have for the plan as a whole. The ability to see where one is going, to see where one is along the path, and to foresee unwanted consequences is very valuable in system analysis and design.

Some who are unfamiliar with the jargon and the concepts of system analysis and design may wonder just how a model of organizational behavior fits into the field of psychology which is traditionally oriented to the study of the behavior of the individual human being. John L. Kennedy, one-time member of the RAND Corporation staff, current chairman of the Department of Psychology at Princeton University, and consultant to SDC, has been insisting for years that an organization is an organism--an organism whose skin can be penetrated and whose inner workings can be observed and understood without altering their functioning. Instead of undecipherable nerve messages, messages are in clear English and their functions are detectable. Certainly the hope is that understanding of organizational behavior will also lead to insights into individual behavior.

Models, such as the one offered here, are visible presentations of observed or hypothesized relationships--a map of a theory, if you will. If they are good maps, they should lead us to better behavior management and also enable us to recognize areas as yet unmapped. For example, when I put on my hat as a clinical psychologist I become quite interested in the distinction between the Event Memory function and the Guidance Memory function. What intrigues me here is the notion that much of current psychotherapeutic endeavor can be conceptualized as searching the individual's Event Memory to learn how he evolved his Guidance Memory. Recent experiences in a limited practice of my own suggest that therapy can also take place where the patient is led to deal almost entirely with his Guidance Memory, his goals and the consequences of his daily behavior, with but little reference to his past. And when I think of little Johnny generating an input to his Guidance Memory to the effect that "If you really want to play with matches, do so where the folks can't see you," I sense that something is missing from the model, namely, an Inference Generator function. Admittedly, this is a pretty sketchy tying-in of the paradigm with individual behavior but it does suggest that it may be done.

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CHAPTER 15

JAMES W. SINGLETON

THE MAN-MACHINE PARADIGM IN LARGE INFORMATION PROCESSING SYSTEMS: THE PROCESS OF COMMAND CONTROL SYSTEM DESIGN

Preceding speakers in this session have described distinguishing characteristics of military command control systems and have discussed the importance of designing such systems to meet the commander's information requirements. Equally as important as the design techniques employed to satisfy this requirement--operations research, human engineering and the newer "system engineering"--is the methodology applied to assure effective design control. Experience with numerous command control projects suggests that there is a management methodology to control the technical design which will assure that the operating system satisfies the information needs of the using military command.

The three classes of elements which must be developed in a command control system, and which must be controlled during development, are facilities, hardware, and software.

Facilities. Typically, facilities requirements are technologically straightforward in command control system projects. Included here are the building and floor space requirements, power supply, wiring and electrical circuits, air conditioning, etc. These do not represent a problem in the technology except in special cases. When survivable facilities are required, one may encounter a problem, but ordinarily not otherwise.

Hardware. Under hardware is included the computing equipment, both central processor(s) and peripheral gear, the communications that permit the acquisition and transmission of data, and the input-output equipment which bridges the computer and the external world. Included as part of the input-output are operator displays and intervention controls, by means of which system operations personnel sample the information that is being processed within the machine and query or control the system performance.

Software. "Software" includes techniques for performing data processing. Three techniques are included: first, design documentation, which states the rules and procedures which are to be performed by the computer programs. Next are the computer programs themselves, both operational and utility. Third are procedures and guidelines for selection, orientation and training of system operations personnel, probably akin to what the Air Force refers to as QQPRI--Qualitative and Quantitative Personnel Requirements Information. Operator methods and procedures handbooks, often

referred to as positional handbooks, might be included as a system exercise and training capability for use in the post-operations phase of the system.

Having described the major classes of elements or components that go into a command control system, let us turn to the stages of the system engineering development cycle for such a system. They are advanced planning; system performance description; system design specifications; production; installation, test and evaluation; and operations.

Table 1

COMMAND CONTROL SYSTEM

Engineering Development Phases

Phase	Output
Advanced Planning	Objectives
System Performance Description	Functions
System Design Specifications	Tasks
Production	Products
Installation, Test and Evaluation	Performance Measures
Operations	Useful Work

The output of each of these development phases varies as shown in Table 1. One expects a statement of the user's system objectives or operational requirements out of the phase of advanced planning; a functional description of the operating system performance out of the system performance description phase; task analysis out of the system design specifications phase; tangible hardware and computer programs and their associated descriptive documentation out of the production phase; performance measures out of the installation, test and evaluation phase; and, hopefully, some useful work out of the operations phase. The first three of these classes of output are essentially paper products--documents which contain increasing levels of detail of the design to be implemented in some tangible hardware and computer programs. Performance measures are test results, a sample of

how the system performs under controlled test conditions. The useful work may be anything--displays, reports, or message transmissions.

Let us now place the phases for development of hardware and software in schematic diagram form (Figure 1). Two preliminary comments are in order about this Figure. First, you will detect that a different number of boxes is allotted to software development than to hardware development. In general, computing equipments are designed and built in advance of the definition of the particular job to which they are to be applied. Manufacturers didn't wait for a particular application before electing to go from vacuum tubes to transistors: it was intrinsically desirable. Therefore, the words, "Equipment Configuration Specification and Production", imply that the problem is that of selecting available equipments and putting them together in an appropriate configuration. This is the essence of the concept of general purpose equipment. The same is not true of software. No one has yet built a general purpose, off-the-shelf computer program to perform bomb damage assessment or threat evaluation. You wait until you know what the specific job is and then sit down to invent the computer program to perform the function. In general, software for command control systems is invented from scratch and is tailor-made for the individual application.

Second, the color coding is intended to imply that the user has a role that completely bounds the process of development of a command control system, starting with the advanced planning, going into what is shown as technical management and design control, clearly encompassing the operation of the system once it is turned over, and going on to include continuing exercise and evaluation of the system. In fact, one can visualize command control system development as a series of cycles, such that modifications, improvements and new requirements are fed into an on-going and successive development process.

The purpose of Figure 1 is to serve as background to a discussion of the three major tasks which must be dealt with to assure that the operating command control system satisfies the information needs of the using military command. These tasks are: (1) establishing system requirements; (2) establishing and maintaining communication between the user and the system development agencies; (3) establishing and maintaining communication between the using command and the operating system.

Establishing System Requirements. System requirements or objectives are the output of the advanced planning phase. They are derived by matching the job that the user is required to perform against the state-of-the-art of the information processing technology to determine that it is feasible and practical to improve performance of that job by the introduction of computer technology. Documentation of the system requirements should include user's mission; system performance criteria, including acceptable response times for modification of the command control system; system boundaries and interfaces; and system constraints, including schedules, costs and priorities among requirements objectives.

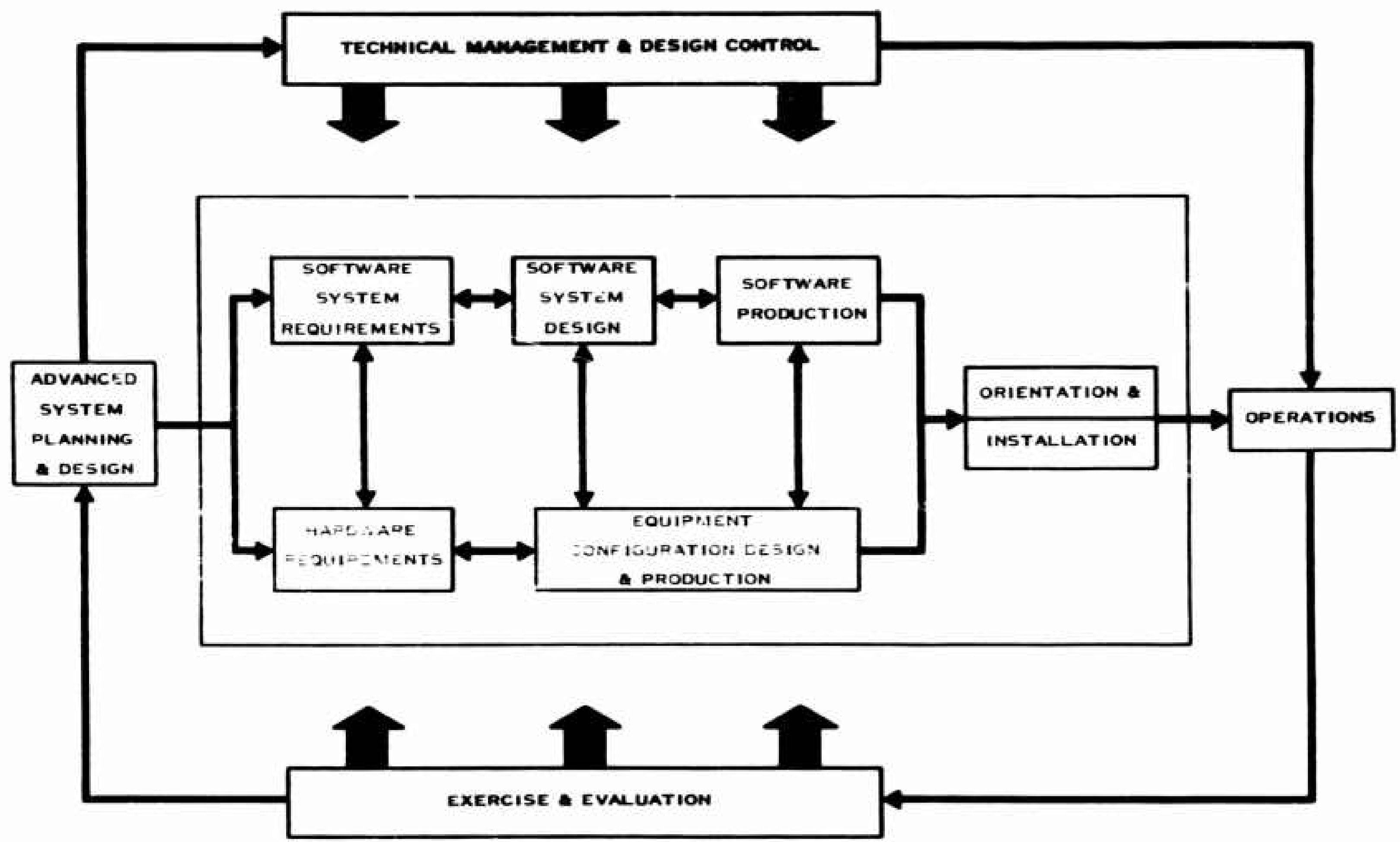

Figure 1. Management Design Process for Command Control Systems

Communication Between User-Developer(s). The entire process of command control system development can be thought of as one of translating from the system requirements that start the process, through the functions and task descriptions, to tangible products and the final operating system. The user must exercise continuous technical management and design control during this translation. This is true by virtue of the fact that he is faced with the introduction of the new and technical nomenclature of information processing as development proceeds, because the process is attended by an explosion in detail, and also because design trade-off is conducted continuously and obscures the relationship between initial requirements and resultant operating system components. Ways in which the exercise of technical management and design control can be facilitated are through the requirement for adequate design documentation in the functional and task specification phases, rational analytic proof of proposed design techniques and procedures, and by adherence to a schedule of regular review and concurrence meetings.

Communication Between User and System. As early as possible, it is desirable that the user begin to develop working familiarity with the emerging operating command control system. One way to accomplish this is by means of design verification through design simulation exercises, operational experiment and pre-operations exercise, test and evaluation. In addition, use of higher order procedure-oriented languages in computer program production will be found easier to understand than the machine level languages previously in use. Thirdly, systematic administration of post-operations exercises for training and evaluation will assist in continued controlled evolution of the system over time.

The problem with a schematic diagram of the command control development process is that it makes the process appear more static and orderly than it really is. In the real world, development phases overlap, iterate and move ahead dynamically. It is also certainly true that the diagram shown here is no better than any of a large number of others that have been or could be drawn. Be that as it may, the development of complex man/machine command control systems is a rational process in which development phases, management controls and pitfalls can be identified. This paper has presented a methodology that can be used as a road map for this purpose. Establishment and adherence to this or a similar methodological map can assure understanding on behalf of the military user with the command control system created to satisfy his information needs.

PART VII

IMPLICATIONS OF DATA TECHNIQUES AND INFORMATION PROCESSING METHODOLOGY IN COMMAND AND CONTROL

INTRODUCTION TO PART VII

Dr. J. C. R. Licklider, formerly of the Advanced Research Projects Agency, Department of Defense, and now with the Thomas J. Watson Research Center, Yorktown Heights, New York, was the invited principal participant and chairman for Part VII. The purpose of the session was to explore the implications of data techniques and information processing methodology in command and control systems.

Chapter 16 was prepared by Dr. Frederick B. Thompson, General Electric Company (TEMPO), Santa Barbara, California. Dr. Thompson examines critically the concept of data base as an accumulation of updated items incorporated in a broad spectrum of facts. He adduces arguments for a dynamic data base embodying the current concerns of a particular headquarters. Changes in environment, capabilities, and objectives imply necessity for change in the data base. Data--reports of observations--are meaningful only in the context of motivations, goals, and value structure. In the interaction between data and context, the available data set limits on what can be controlled, and the motivations to control determine the requirements for data.

CHAPTER 16

FREDERICK B. THOMPSON

NATURE AND ROLE OF DATA IN COMMAND AND CONTROL

Work on military command and control systems has been marked over the last few years by attempts to build large data systems which automatically update the extensive files of data conceived as essential for the decision maker. However, these attempts have not been completely successful. In this paper, an alternative conception of the appropriate data base is presented. In this conception the data base is dynamic and responsive rather than inclusive. It is the embodiment of the current concerns of the particular headquarters. Thus, rather than striving for objective universality, it strives for relevance. This conception stems from the nature of data itself and from the importance of change. For the problem of data in command and control rests, first, on the relative minuteness of the sample of data that constitutes our data bases, and second, on the necessity to constantly restructure this sample in all its dimensions if we are to maintain hold of that small part that is relevant in a sea of accessible observations.

By an item of data I mean a report on an observation. I shall assume that these items of data result in a clear-cut way from actual facts accurately observed and reported. By focussing on data in this sense, I bypass the problems of perception and reporting; I am still left with the basic objective aspects of the content of communication and information. How we perceive and encapsulate data is left for others; I will start with data and build from there. That there are data in approximately this sense seems a reasonable assumption.

THE ROLE OF DATA

The problems we are left with are not the problems of the individual item of data. Rather, they concern the way we are to handle and make use of large collections of data items--the problems of data in the large. In the development of a data base, over and above the tasks of insuring the collection and updating of individual items, crucial questions concerning the data as a whole remain to be determined. The central issue which concerns us is the way these questions concerning the data in the large are to be answered. In order that this issue can be seen clearly, we will start with three examples of such global questions.

The first example of a global question is: how should the data be organized? How one chooses to organize the data will make a big difference in how it can be effectively used. As an example of the effect of organization of data, we cite the recent major shift in the organization of accounting information in the Department of Defense. Accounts had previously been maintained by line item, and items of a similar nature from the procurement point of view were grouped together. At the direction of the comptroller, accounts are now organized around the various missions to be performed. One can now immediately determine the total costs of operating a tactical air wing, whereas before, accounts for the multitude of line items involved in such operations--air base costs, personnel costs, etc.--were distributed throughout the accounting system and were virtually inaccessible as a group. This conceptually simple yet major revision of Department of Defense accounting practices has resulted in a very significant increase in the visibility of the costs of alternative weapon systems. What is important here is that these benefits were brought about simply by a change in the organization of the same basic data.

A second question about data in the large concerns the specificity of the data. Since each category of data can be ramified ostensively without end, one must stop somewhere, and the point at which one stops, the "cut" that one takes in level of detail, is of great significance in what use can be made of the resulting data. Consider, for example, one item that might occur in the data files of the Air Force in the Pentagon--the number of Military Air Transport Service aircraft ready to fly at Tinker Air Force Base. This seems a very hard, highly specific item of data. But let us consider it a moment. Does it include those planes that are in maintenance but could take off in an emergency? Does it account for availability of crews as well as aircraft? Is one of the planes fitted out for carrying important personnel? Do any of them have the capability to airlift some specified number of tons across the Atlantic? Each of these questions, and a host of others, may at some time be of importance, yet each remains unanswered by the single item which on onset seemed so specific. The cut taken in defining the items to be included in a data base makes a great difference in its usefulness.

A third question about data in the large concerns the degree of interconnectedness. To illustrate what I mean by interconnectedness, suppose we had the longitude and latitude of all major ports and all combat ships. Because of the commonality of longitude and latitude in which the positions of ports and ships are given, their geographic relationships can be seen--a positive degree of interconnectedness in the data. By adding the cruising speed of each ship and a formula for computing the distance between points on the high seas, the degree of connectedness is greatly increased, for now a much richer set of interrelationships is implicit in the data.

We have considered three important aspects of data in the large: organization, cut, and connectedness. These three, plus other similar

aspects, determine what is visible from the vantage point of the data base. It is clear that from a data base that contains no mention of naval matters either explicit or implied no naval matters are visible, i.e., the data base yields to the user no understanding of such things. But our point here is that visibility from a data base is vitally affected by global properties of the base as well as whether it does or does not contain a given item.

To illustrate this matter further, if one is given an equation together with adequate initial conditions, the solution of the equation is uniquely and completely determined. Why then do we go through the considerable computational work of "solving" the equation? In order to make the solution visible. In a very real sense this computational effort is a reorganization and extension of the original information. All of planning can be looked at in the same way. Given the initial conditions, objectives, and planning factors, the development of a plan is a process organizing this material in a way that makes visible the steps to be taken to accomplish these objectives.

Thus the questions of data in the large are questions of what is to be visible. Certainly what general categories of data are to be included is such a question. But so are the questions of organization, cut, and connectedness. On what basis are the decisions on these as well as other similar questions to be made? What is it that should determine the character of the data base of a military headquarters? Equivalently, how is it to be determined what should be visible to a military headquarters?

The data base should certainly be adequate for the coordination of the operations of the command. Thus the data base must include the detailed capabilities available to the commander. But what capabilities are to be included? Certainly the fact that one of the enlisted men can play the bagpipes can be omitted. But some measure of firepower must be included. How is this question as to cut to be made?

Well, the cut to be taken in the inclusion of capabilities must depend upon the objectives to be met. These objectives themselves constitute an important part of the data base. How are they to be organized? Certainly to list the objectives alphabetically would hardly be useful. On the other hand, their temporal interrelationships and their geographic interrelationships are of importance, and the effectiveness of the data base can be increased if these interrelationships are reflected in its organization.

But precisely how the objectives are to be stated depends strongly on the environment in which the command's operations are to be conducted. How do objectives and capabilities relate to environment? The degree to which the headquarters can effectively deal with these interrelationships depends on the connectedness of the data base.

The data base is a mediating instrument between capabilities, objectives, and environment. No one of these facets of the operational situation can stand alone. One's objectives make no sense without knowledge of capabilities and environment. How should one describe the environment if one knows neither objectives or capabilities? And the relevance of this or that aspect of capabilities can be seen only in the light of one's objectives and environment. Indeed, the bringing into consonance of objectives, capabilities, and environment is the very essence of command decision making. It is when the elements of the situation stand clearly revealed in relation one to the others that command can be exercised and control maintained. And the data base is the instrument through which these relationships are visible.

This is the visibility that the commander and his staff seek. If this visibility results from decisions of organization, cut, and connectedness, then these decisions are of direct concern to the commander and his staff. Indeed, it is to precisely such questions that the staff attends. We have seen that planning is in essence reorganization and ramification of the data base. Intelligence is nothing if not the nurture and feeding of the data base. What is it in the environment that can be exploited; how would redeployment affect capabilities; what first step toward the overall objective is compatible with our current position? Iteration and reiteration of these questions in a thousand variants is the essential concern of the staff. And since the answers to these questions become a part of the data base and affect reverberations throughout the base, it is the molding, ramifying, extending, and organizing of the data base that is the behavioral manifestation of staff work. In clear analogy to what the cognitive psychologist refers to as the mediating cognition, it is the data base that functions as the mediating instrument in the military staff.

THE IMPORTANCE OF CHANGE

This notion of data base contrasts sharply with the notion that the data base should store a broad spectrum of facts which can be retrieved by the staff on demand. It is this latter notion embodied in large formatted files of data in fixed organization, cut, and connectedness that comprise so many of our command and control system designs. Is it the case that there is a fixed, circumscribable reality which encompasses the concerns of a headquarters? If there is, then the prestructured files with the inherent opportunity for efficient storage and retrieval design is the correct solution. Then the questions of organization, cut, and connectedness should be made by the system designers upon the careful analysis of established requirements. Yet there is a question whether this is indeed the case. The comments of one of the principal programmers on such a system give a clue to what is happening. As he finished describing the elaborate file system, the huge storage of millions of items of data, and the volume of tabular listings distributed

periodically to the staff, I asked him what problems remained. He replied that somehow the staff refused to use the system. They still maintained their 3 x 5 card files, their manual postings, and "antiquated" procedures.

The basic issue is that of change. Certainly the values assigned to the various items of data change. But does change also reach to the questions of data in the large? Is it necessary to constantly reorganize the data base, to ramify here and prune away detail there, to build in new pathways of connectedness while recognizing that others no longer apply? I believe that this is the case, indeed that careful observation of a military headquarters establishes beyond any doubt that change is of the essence.

What changes? Certainly the environment changes, for the enemy is constantly modifying his posture with the direct intent of making obsolete our ability to react to it. Capabilities are changing, for technological advance is continuous (quite in contrast to the false paradigm of the stepwise advance in terms of major weapon systems). And objectives change, even the gross objectives, for the political sources of such objectives both external to and within the Defense Department are constantly changing. These changes in environment, capabilities, and objectives resulting from influences external to the data base imply the necessity of change in the data base. However, if the base were only a depository of data items whose interrelationships were seen only by considerations external to the base, the degree of change in the base would be minimal and could perhaps be accommodated within a pre-existing structure. It is essential to recognize that this is not the case. If the records in the data base show an increase in enemy capability, it is not only this increase in capability that now must be changed. Even with no externally generated change in gross objectives, the detailed objectives, which are certainly delineated in the base, must now be modified in light of the new threat. If a new weapon is introduced by the enemy, not only is this to be noted, but a reassessment of our own capabilities, introducing a measure of their effectiveness against this new weapon, must be incorporated in the base. Similarly, any change induced from outside in capabilities or objectives induces internal changes in environment objectives and capabilities.

To bring this down to particulars, consider one area of major change in the data bases of major military headquarters during the last decade. Consider the change due to the development of large-yield warheads. Previously, our capability for strategic disruption of the enemy depended on our knowledge of the exact location and capabilities of his entire munitions and munitions supporting industry. Thus the target intelligence data base contained many hundreds of industrial facilities, their location, layout, production statistics, etc. Further, it was necessary to develop the overall damage from attack and thus interindustry flow statistics were obtained, etc. This now has all changed. Strategic disruption now reduces to the destruction of major complexes, not of individual industries. Having been cognizant from a rather neutral position of these matters over the last decade, I have been impressed by the sweeping nature of the change in the data bases associated with these matters.

These major changes in all dimensions of the data base are not made all at once. In reference to the above example, I remember the first attempts made ten years ago to introduce into target intelligence a few considerations of enemy operational practices. That first step, hotly debated at the time, has affected the organization, cut, and connectedness of this data base not once, not recurrently, but on a continuous basis ever since. For example, the day came when the technological change from piston aircraft to jets was complete and someone wondered why the target category of tetraethyl lead was still maintained. Doing away with this category was not only a matter of deletion of a few targets. It called for revision of parts of an economic interaction model, modification of the target value of certain target complexes, reassessment of targeting aspects of war plans, etc. Such questions calling for data base revision are the rule, not the exception. An experienced comptroller said to me recently that this year's accounts are always easily accessible, it is last year's that are hard to use. Why? Because categories and procedures have changed just enough so that last year's records do not fit our current ways of thinking.

It is the data base that is the instrument by which the staff is able to sense, follow, and anticipate change. Change can be "seen" only against some reference to which it contrasts. The data base is that reference. Further, the scattered observations that we can make are far too sparse to provide an adequate feel for the continuous flux of our environment. It is the data base that fills in between our scattered observations, and in its own continuous evolution provides the sense of trends and continuity. As a very striking illustration, consider the situation immediately following the onset of war in a major combat operations center. The critical messages, the conflicting reports, the bits and pieces of the situation that are visible would make no sense whatsoever without the underlying data base. Further, it is only on the rapid evolution of this base that the commander can stay in touch with the situation. It may be portrayed as a battle map, or as orders of battle, or in a variety of forms. Finally, in the prebattle planning process, it is the data base that provides the context for war gaming and simulation that projects the present situation into the future, and therefore anticipates and prepares for the future.

Earlier the question was posed: who is to determine the character of the data in the large? Clearly this determination is the continuing culmination of the day-to-day work of the staff. This determination is not an explicit concern but results from the necessities of maintaining that and only that which is relevant, of maintaining the clearest visibility of the command's business. In this task it is the dynamic data base that is the instrument of the staff's effectiveness.

This conception of the data base is in sharp contrast to those which are in vogue in military command and control systems today. I should like to mention explicitly several points of difference. First, it is currently thought desirable to standardize the categories of data and data organization. The opportunity to capitalize on the economies of coding and communication capabilities seems irresistible. The result is that each headquarters finds the structure of the base too static and inflexible to meet their needs. The coordination of any suggested change throughout the command structure takes far too long. What passes for the data base becomes a burden which must be maintained in addition to the actual base which has reverted to manual records and scattered files.

Second, although the organization, cut, and connectedness of the base were carefully designed on the basis of a thorough operations analysis, this analysis becomes obsolete more rapidly than the elaborate electronic system can be implemented. As a result, the data categories to be reported by subordinate commands no longer apply. Because of the inflexibility of the system, false reporting becomes the common practice. As an illustration, visualize that all our defense bases may be required to file daily reports on the number of planes on the ready line. Let us suppose that when this requirement was imposed planes were put into maintenance only when significant work had to be done on them and it was usual to have only a small part of one's complement of planes in maintenance at any one time. Now suppose a base decides to put all planes in maintenance whenever they have been operational, but to do so in such a way that each can be airborne in a minimum amount of time. This new maintenance procedure may result in a significant increase in plane availability. But how is the daily report to be filled out? The necessity for "proper corruption" is almost universal today. Each of us has had to be properly corrupt when reporting some nonsense statistic in the recent past, but possibly we have felt our small fabrication has been an isolated case. However, the practice of such proper corruption in data reporting can reduce the validity of data in major data files to close to zero.

Prior to the current upsurge in the extensive automated data systems, it was presumed that the staff would always authenticate the reports that they made part of their data base. This authentication involved the evaluation of the item in light of the staff's own evolving data base and also the judgment as to its relevance. Although the requirements for data have certainly increased and the old methods are no longer adequate, our present solutions in terms of rigid data systems are equally inappropriate.

Let us turn directly then to the conception of the data base as the mediating instrument of the staff. Two aspects of this conception stand out as of particular importance. First, the fact that the data base in all its aspects is the instrument solely of the staff imposes a certain discipline in its maintenance which is the proper discipline of the staff--namely the necessity to make the judgment of relevance. The perspective

on which command must be built comes from the staff study, the probings and cross checks of events and reports, and the constant projecting into the future to find the trends and anticipate the future problems. But these are the very activities that maintain the relevance of the base. It is this perspective that must be constantly rebuilt into the base and added to the incoming communications if they are to be more than superficial balms to the frustrated commander whose staff is following rather than anticipating. Such a relevant data base has always been the hallmark of the first-rate staff officer. But it must be brought out from his desk drawer and fused into the dynamic instrument and discipline of the whole staff if today's requisite effectiveness is to be realized.

Second, it is precisely the constant shifting and renewing of data requirements that results from the dynamic data base that is a principal means of control. The static data system, however complete, establishes its own patterns of compliance, at both ends of the reporting channels. The filled-in form that is clearly never read opens the door to proper corruption. The received form that is clearly of little relevance dampens the sense of responsibility. It is when an order is accompanied by a request for the necessary data to insure compliance that it is an order indeed. If reports are filed only when clearly relevant, then and only then do they insure an audience.

A data request, tailored to the relevant matters at hand, carries much more information than the necessity to report. It conveys what is to be visible and thus, more than any other communication, it tells what is to be done, what is expected. The smart student soon learns to examine the graded paper to see what his professor is looking for. And the smart staff knows both how to read and how to impose data requirements. In this process the data base itself plays an important role. One needs to know what is not visible as well as what is visible. It is by working with the base that one identifies that collectable input which, when added to what is already in the base, can imply the desired information.

Thus, the dynamic data base is the instrument of command and control in ways not realizable by the large static data system. It supplies the cohesion that knits the staff together and the discipline that insures the relevance of its concerns. It is the visible measure of staff effectiveness and the instrument through which it can control.

TECHNOLOGICAL CHALLENGE OF THE DYNAMIC DATA BASE

The concept of the dynamic data base presented above imposes certain technical requirements for its realization. If the staff is indeed to work with and communicate through its data base, it must have direct and immediate access to it. The language for this access must be the common language of the staff--English, modified and modifiable to include the

special idioms of the staff. Through this direct access, the staff must be able to manipulate, reorganize, and extend the data base as well as query it. Since the structure and inclusions in the base will be changed by various members of the staff, access by any one member of the staff cannot be predicated on his exact knowledge of this structure.

These are stringent requirements of a very different nature than those frequently imposed upon an information system design. However, if we step back to gain perspective concerning the course of information system development in support of staff work, we see that these requirements at manual speeds and limited volumes of data were met and indeed characterized the information systems utilized by military staffs prior to the advent of computer systems. The greatly foreshortened response times and greatly increased areas of concern demanded of current military staffs have made these manual systems obsolete and incapable of handling current loads. It is natural that electronic data processing techniques were brought in to aid the staff. That their first modes of application would follow practices of business data processing also was to be expected. But what now of the conception of the dynamic data base presented here? Can we now progress technically to systems that can implement this concept?

PART VIII

EXERCISING TEAMS IN MILITARY SYSTEMS THROUGH THE USE OF SIMULATION

INTRODUCTION TO PART VIII

Part VIII was the responsibility of Dr. William C. Biel, Systems Development Corporation, Santa Monica, California. In Chapter 17, Dr. Biel emphasizes the importance of developing training requirements concurrently with the system and of defining operator tasks at a sufficient level of detail to specify equipment and computer requirements and functions.

Psychologists, Dr. Biel asserts, must take responsibility for seeing that appropriate training is planned for, even if, to do so, they have to learn additional skills and participate in nonpsychological analytical work.

Dr. Harry H. Harman, also of SDC, author of Chapter 18, first gives a definition of simulation as "the act of representing some aspects of the real world by numbers or other symbols that can be easily manipulated in order to facilitate its study". Distinguishing between operations simulation and symbolic simulation, he notes also the dependence of one form of simulation upon another. He uses examples of particular systems to describe the operations simulation technique used in exercising crews synthetically either in their actual operational setting or in specially designed simulation facilities. The "crews" participating in the exercise may number several thousand individuals. For his examples, Dr. Harman draws upon military experience with operations simulation and touches upon simulation techniques for aerospace crew training.

In the third chapter (19) of this series, Dr. M. Stephen Sheldon, also an SDC scientist, considers two major problems in achieving evaluations of system training results that are "empirical, quantifiable, communicable". The first problem is the development of measurable criterion variables to assess crew performance. Dr. Sheldon would base decision as to what observations should be made on an operational definition of the overall mission of the system. The second problem concerns the selection of the situational variables--defined as the parameters of enemy action and the battle environment--which must be made part of the simulated exercise. "If one omits any interfering element that the opposing system is capable of producing, all measures taken in that simulated situation are questionable." Dr. Sheldon further warns that training in an environment with such omissions can do more harm than good, lulling the crew into thinking that "the enemy is as benign as the false representation".

CHAPTER 17

WILLIAM C. BIEL

PLANNING FOR TEAM TRAINING IN THE SYSTEM

It is not sufficient for individuals to receive only basic and individual training if they are to perform well in most operational systems. Some type of training is needed to integrate these individuals into an operational team and then to integrate these teams into larger units, even into total systems. These training techniques need to be used frequently to improve the operational readiness of the system and to maintain it at a high level of proficiency.

Two general types of operations training, which attempt to bridge the gap between individual training and good operational performance, are described here. These are characterized in Figure 1. On the left in the figure is shown a representation of operational exercising (or training). This type of training program exercises a team or teams of men in the operational system itself by using integrated, realistic, but simulated inputs. This training might be for a crew in one center; crews in several centers working together with a higher echelon; or perhaps crews in many operational centers, with high-level headquarters participating. Simulator exercising (or training) is shown on the right in the figure. Here a team or teams of men are exercised in a large simulator used to duplicate or simulate the essential operational aspects of the total system environment. These exercises might be for a single team, several teams, or perhaps, as in the case of the Navy, for a total task force. Briefly, in the first type, the training is brought to the men; in the second, the men are brought to the training.

A type of system particularly suitable to either of these types of training is one in which groups of men work together--with critical interactions and with different but related tasks--to receive and process data, make decisions, and take actions with the aid of computers. In certain systems, the processing of symbolic information is predominant--in contrast to direct physical contact with an adversary. Symbolic information can easily be simulated for training purposes. This paper emphasizes the development of training techniques for teams of men who are to operate these information-processing systems.

1. OPERATIONAL EXERCISING. **2. SIMULATOR EXERCISING.**

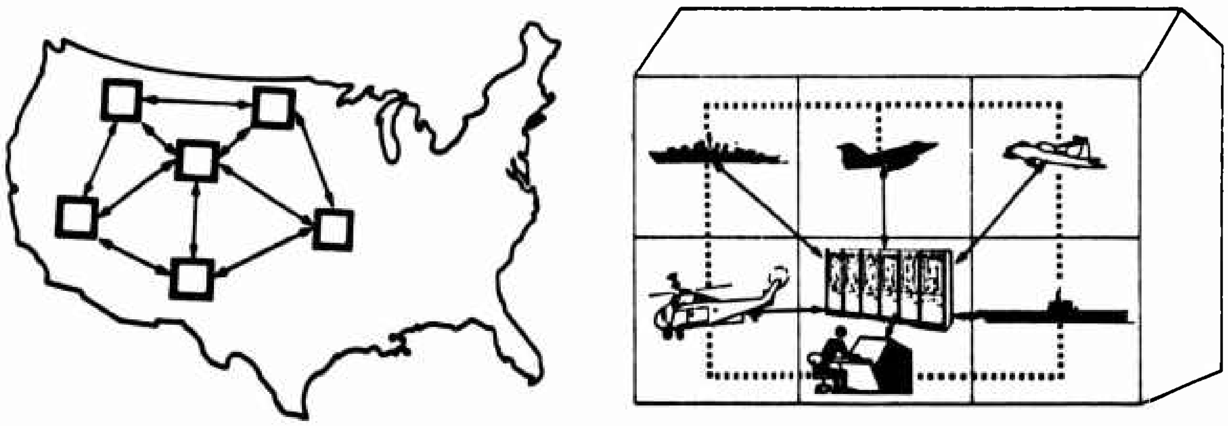

Figure 1. Two types of operations simulation for training

In the first type of training--exercising in the operational system--the number of computations and the amount of integration of stimuli needed to produce materials for the training situations require the use of a computer. During such exercises, a computer is commonly used to generate additional stimuli in response to crew actions, to record the actions of the individuals in the crew, and to analyze their responses in terms of the inputs or stimuli to the system. In the second type of training--the use of a large simulator--the generation of stimuli and the constant changes in the problem situation due to the interactions that are taking place require the use of a computer in the simulator.

Development of these types of training programs requires considerable lead time and integration with other system developments. In the early planning for a new system, it is essential that consideration be given to, and decisions made about, the development of the required training programs.

In the past there has always been a series of general phases in the development process for an operational system. The Air Force has identified the following general phases of its system development: a Conceptual Phase, an Acquisition Phase, and an Operational Phase. In February 1964, the Department of Defense issued a directive that introduced another phase into the development process--the Project Definition Phase--and stated what must be done during this new phase (DOD, 1964). It is applicable in medium- to large-sized systems. Specificity is rapidly developing in the other traditional phases. Requirements are being laid down concerning what consideration must be given to, and what decisions need to be made

about, development problems--including training (AFR, 375-4, 1963; AFSCM, 375-4, 1964). Figure 2 shows the general phases through which this development now proceeds in the life cycle of a system in the Air Force.

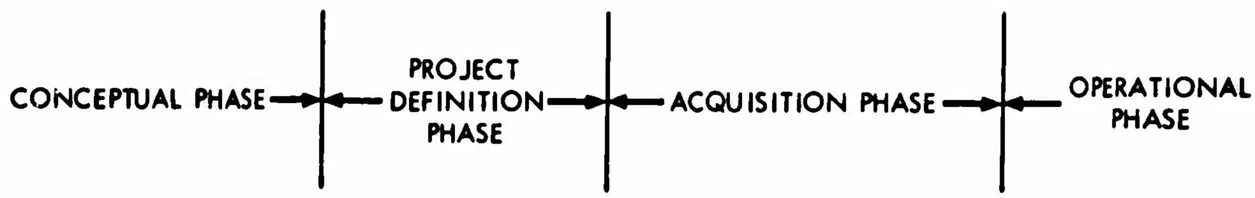

Figure 2. Air Force system life cycle phases

In the Conceptual Phase, many activities take place that are familiar to scientists: research, exploratory development, and advanced development. In the Project Definition Phase, preliminary engineering and contract and management planning are accomplished, whereas in the Acquisition Phase the traditional product development, production engineering, production, and installation occur. These all lead to the Operational Phase.

Figure 3 shows a breakdown and sequence of certain critical and more formal activities during the Conceptual Phase in the life cycle. Many more activities take place than are shown in this diagram, but some of the most critical have been collapsed into these six boxes. Before describing the contents of these boxes, it should be stressed that system analysis, leading to an understanding of the system requirements, begins early and continues through the Conceptual and Project Definition Phases. It is paralleled by more and more detailed studies of how best to meet these requirements. During the analysis, consideration must be given such things as national defense, objectives, threat information, current system objectives and operations, new technology, future objectives and requirements, strategy, cost effectiveness, and many others.

Following early analytical work, a detailed statement of the general operational requirements of a required system are stated, as shown in the first box in the diagram. Planning studies are conducted to devise system concepts that might meet these requirements. These are followed in turn by feasibility studies to select the preferred system concept as shown in the third box. Then a document is issued that states formal system requirements. Preliminary system performance characteristics are specified; and, finally, a Preliminary Technical Development Plan is produced and forwarded, along with other documents, to the Office of the Secretary of Defense for approval.

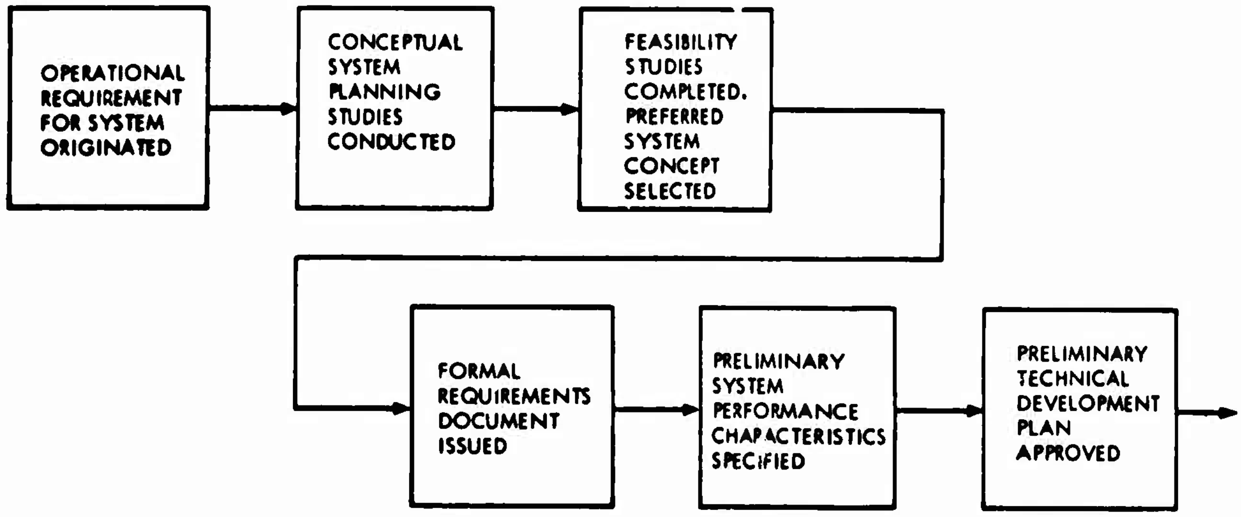

Figure 3. Conceptual phase

The early Conceptual Phase has been described because it is important to understand that the training requirements must be specified during this early phase and must be stated in the Preliminary Technical Development Plan. Admittedly, this plan has not yet been formulated in great detail by this phase in the sequence; but, if the system is of the computerized information-processing variety--one in which a system-exercising capability will be needed--special requirements will undoubtedly be placed on the design of the computer program, on the equipment, and on the personnel. If, on the other hand, the system requires a simulator for team training, then this requirement must be stated in the plan.

To be able to decide whether the system plan is an appropriate one for an operational exercising program, or whether a team, multi-team, or large system simulator will be needed, and then to be able to design the training program, the training designer must understand the operational requirements and the preliminary design for meeting them. In other words, it is necessary that he participate in some of the early analytical work. He likewise should have a thorough understanding of the concepts of operational exercising and simulator training, and of what can be achieved through such training. Other individual training, human engineering, and personnel requirements also must be given consideration in this early stage.

In the Project Definition Phase, shown schematically in Figure 4, the details of the planned system are worked out so that specifications and a final report can be written. At the end of this phase, a Proposed System Package Plan, along with other documents, is submitted to the Office of

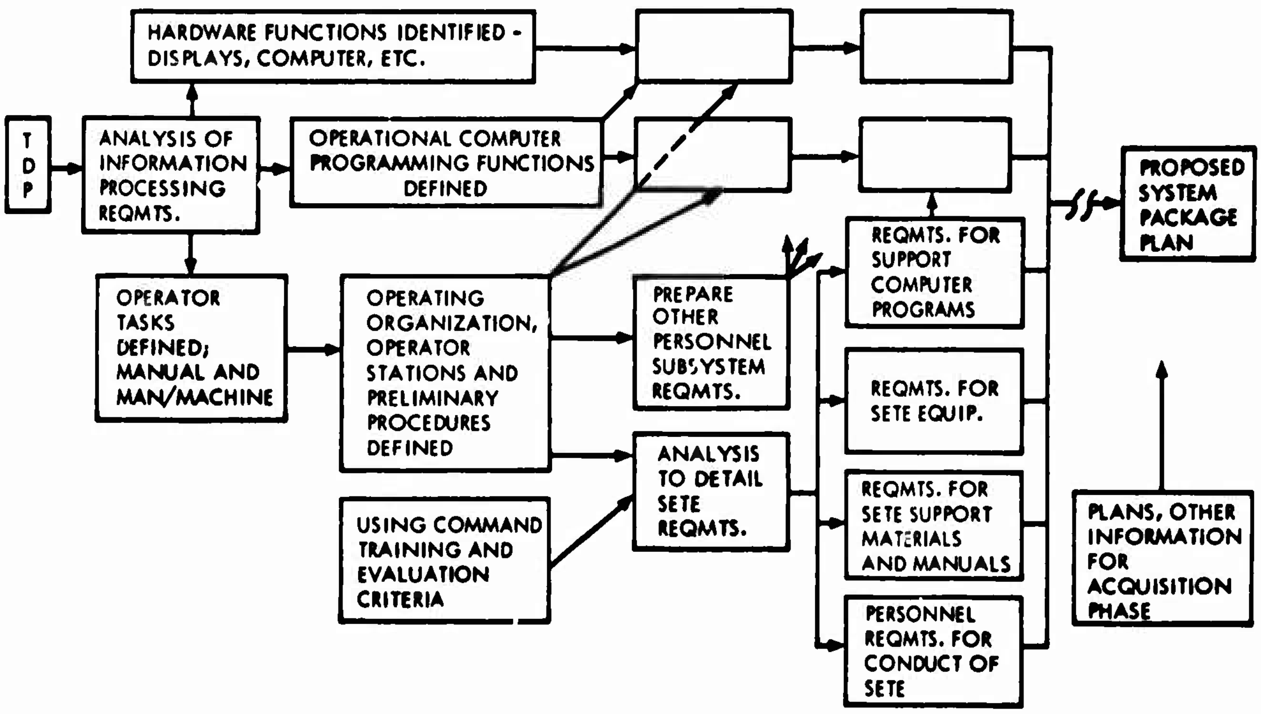

Figure 4. Project definition phase emphasizing system exercising for training and evaluation (SETE)

the Secretary of Defense for approval and funding. Then the system life cycle proceeds to the Acquisition Phase, where full-scale system development takes place.

Finally, the work on development and installation is followed by an Operational Phase.[1] The flow shown in Figure 4 is a major abstraction of many activities that go on during the Project Definition Phase; justice is not readily done to the amount of work undertaken here. However, the boxes selected for discussion do assist in making several points in connection with the early planning and design work for operational exercising and other types of training, and in connection with the interactions that are required with other activities in the technical aspects of development during this phase.

[1] Neither the Acquisition Phase nor the Operational Phase are described in this paper.

Beginning on the left side of the figure, one notes the approved Technical Development Plan (TDP), which represents the last box in the previous figure. In the next activity, a more detailed analysis is made of the information-processing requirements of the system. At this point, it is possible to break out detailed requirements for three of the technical areas of design for the system:

1. Identification of the hardware functions, including those for displays, the computer, etc.; this is shown in light gray in the figure but no details are given of the refinement activities.

2. Computer programming activities, beginning with the operational computer programming functions defined; this is shaded a darker gray, and again no details are given.

3. Personnel subsystem activities, grouped in the dark gray area; emphasis in this figure is only on those personnel subsystem activities related to operational exercising, here called SETE for System Exercising for Training and Evaluation; this is the name that has evolved in some systems for what used to be called System Training; only general comments will be made here on activities in the figure that lead to specifications for system simulators.

One of the first personnel subsystem activities is to define the operator tasks. Following this, the tasks are formed into jobs, and the operating organization, the operator stations, and the preliminary operating procedures are defined. These tasks and jobs all interact in important ways with the hardware and the computer programming. These preliminary procedures must be defined to a level of detail sufficient to specify the equipment and computer program performance requirements and functions. Further detailing of procedures will of necessity take place in the Acquisition or full-scale development phase. The activities in the box, which include the definition of the organization, the operator station and the preliminary procedures, constitute a major step in the personnel subsystem activities, and it is from the information obtained here that other personnel subsystem requirements are then further detailed (AFR 30-8, 1964; AFSCR 80-14, 1963). This step includes, among other things, determination of the types and number of operator personnel; collection of human engineering information, including that for the design of the displays and controls; development of the Training Support Package, which breaks down into Training Equipment Planning Information, Training Equipment Development, and Training Facilities. There are many interactions between activities in the personnel subsystems area and the other development activities, but these are not specifically shown in the figure. If a need had been found earlier for a simulator program, it would now be specified at a level of detail corresponding to that for the system; and its interactions with other parts of the development process would be indicated. However, if the system requirements indicated a need for an exercising program in the operational system, it is at this point that the details of this program would be determined. When detailed requirements for SETE are set up, plans should take into account the training and evaluation criteria of the using command.

The results of this analysis and planning establish further requirements and specifications for computer programs, for special equipment, for other materials, and for personnel. If a requirement exists for the operational system to evolve, or to be a flexible system, then the exercising program must be adaptable so that it will fit whatever changes take place.

A point to note about Figure 4 is that all of these very important detailed studies and plans are necessary before a decision is officially made to acquire a particular system. Specifications and planning documents result from all of these studies, and an over-all package plan for the system is proposed for the Office of the Secretary of Defense approval prior to the development and production required in the Acquisition Phase. This figure shows that for the SETE program, or for a large simulator training program, as well as for several other of the personnel subsystem requirements, much detailed planning needs to be accomplished early and many interactions with other designers must take place.

There is now a better recognition of the value of detailed planning for the development of systems. In particular, there is recognition of the value of planning for training and other elements in the personnel subsystem. Psychologists can not sit back and criticize engineers and others for not considering operator problems; psychologists must take the responsibility for seeing that appropriate training is planned for. This may require learning additional skills, participating in nonpsychological, analytical work, etc.; but in any case, it requires understanding of the system and the operations for which the training is being designed--and then it requires <u>doing</u> something about the training design as well as the system design.

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CHAPTER 18

HARRY H. HARMAN

DESIGNING AND IMPLEMENTING THE SYSTEM MODEL

SIMULATION CONCEPT

Once the functions of the real-life system have been analyzed and reduced to operational specifications, the design of a simulation model of the system can proceed. For such a model to be useful for training purposes, it is necessary that it be sufficiently detailed to evoke the kinds of behavior which are characteristically encountered in the real-life situation. When the referent system involves information processing and decision making by men employing complex machines, it is essential that the model created to represent such a system include all the relevant features of the total system. While this is a somewhat circular statement, its intent should be evident. Specifically, a good representation of a complex man-machine system must include people in the feedback loops--to try to simulate, completely, the highly variable, unpredictable behavior of human beings by means of a computer algorithm would either grossly oversimplify the human behavior or else exceed the capabilities of both the most competent mathematicians and advanced computers.

Since simulation has become such a popular tool, used and sometimes misused in a variety of situations, it might be well to clarify its meaning and delineate its application to training. There are many and sundry definitions of simulation (see, for example, Harman, 1961), but we shall not attempt to cover them here. We should, however, refer to the fundamental notion, as given by Webster, that simulation is an act of "assuming the appearance of, without the reality". The paraphrase, "to <u>simulate</u> is to attain the essence of, without the reality", has been made by Thomas and Deemer who advise that "we should deplore the tendency to introduce trappings and ornaments in <u>simulation</u> to gain the 'appearance' of reality when it is the 'essence' which we need" (Thomas and Deemer, 1957, p. 5). Emanating from such fundamental statements are many alternative definitions of simulation according to the particular field of application. These range in emphasis from sampling experiments in operations research and the use of large-scale computers for the study of mathematical representations of a system, to specific working definitions of particular fields of inquiry. What they have in common is an attempt to substitute other elements for some or all of the real elements of a system. Perhaps the simplest and most direct definition of simulation is merely that it

is the "act of representing some aspects of the real world by numbers or other symbols that can be easily manipulated" in order to facilitate its study (Harman, 1961, p. 2).

More specifically, simulation is frequently classified according to the objective or use to which it is put. The principal categories usually employed are evaluation, demonstration, and training. With the emergence of very large military command and control systems, the old trial-and-error method had to give way to simulation as the primary technique for the design and development of such systems, as well as for the evaluation of alternative solutions to system problems. In the demonstration role, simulation serves as a means of indoctrination--to exhibit the feasibility of a complex system. Again, in the implementation and operation of such systems, simulation has been found to be a very effective device for training. Not only have simulators been employed for individual flight instruction in place of expensive and dangerous procedures, but similar efficiencies have been realized in training groups in total system operations through simulation. This is one of the chief objectives of management games as well as the specific training programs of military systems, which will be developed in the remainder of this paper.

So, without further attempt to define simulation, it is perhaps important to note the distinction between the following two types:

Operations simulation is the simulation of operations, in the field or in special facilities, of an information processing system wherein people and computers are involved.

Symbolic simulation is the simulation of an information processing system through symbolic or digital representation of logical relationships, wherein real people are not involved but computers usually are involved.

If we were to consider the several forms of simulation as ordered along a continuum on the basis of degree of abstraction--that is, the extent to which the model is abstracted from the world of nature--then we would place operations simulation somewhere in the center of such a continuum. At one extreme would be the real system itself, while at the other would be the highest degree of abstraction, involving a complete analytical formulation of the system. What is suggested is that a realistic model of the system be created having a high degree of fidelity to the real world, with allowance for the abstraction and substitution by symbolic representation of certain elements of the system. More specifically, by operations simulation I mean the creation of an operational model of the system, choosing the relevant features of the real system for representation, and deciding on the means of such representation. A system may be made up of such deverse elements as people, hardware, operating procedures, mathematical functions, and probability distribution. An operations simulation of such a system might consist of the actual replication of some of these elements and the symbolic representation of others; of course, many details would be omitted.

The dependence of one form of simulation upon another is exemplified in a recent article, "The Human Operator", by Muckler and Obermayer (1964), devoted primarily to the man-vehicle control problem. As appropriate mathematical models are sought to fit human-operator data, symbolic simulations have become increasingly sophisticated. Man as a controller may be viewed as an unusually complex machine--his inputs come from a variety of energy sources and are coded, filtered, and integrated to produce relevant responses to fit the particular system--which certainly is non-linear and error-prone, and, above all, differs from an ordinary machine in the uniqueness of the individual and in possessing the characteristics of motivation. In consideration of the complexity and unpredictability of man's behavior, it is remarkable that any progress has been made in the development of formal analytical models of his performance as a human controller. In the design of manual control systems, at least at the early stages, quasi-linear models of the human controller have been used with some success. Ultimately, however, Muckler and Obermayer state that it is necessary to "use empirical simulation methods because we cannot predict precisely and accurately what the human controller is going to do" (op. cit., p. 66). What they propose as "empirical simulation" is essentially our operations simulation.

There are many advantages of simulation over an attempt to deal with a system itself. First of all, the real system in the field is not as amenable to control as a simulation of it, and the taking of quantitative measurements can be better accomplished in the latter case. More specifically, some of the concrete advantages of simulation include the following:

1. Compression or expansion of real time

2. Ability to experiment, test, and evaluate new systems or proposed changes to existing systems in advance of having to make firm commitments

3. More economical experimentation, both in time and money

4. More precise control of the variables in an experiment, permitting more accurate analysis of results

5. Possibility of the replication of experiments under different conditions

While the foregoing advantages are true of simulation in general (some more uniquely for symbolic simulation than for operations simulation), there are some particular advantages of training in a simulated environment. Exercise situations which might be impossible, impractical, or too costly to create in a real environment become a matter of course for simulated inputs. Usually, a simulated exercise can be run for a small fraction of the cost of a live military exercise, and with much greater flexibility regarding time of day or night and such exogenous factors as weather. Even more important is safety of simulation--no tanks, ships, or aircraft are involved; there can be no crackups, no

damage, and no lives lost. Simulation allows for the possibility of repeating an exercise with exactly the same inputs. It allows the system to develop techniques or solutions in the course of training, and to check these in subsequent replications of an exercise.

Before proceeding to the use of operations simulation in military exercising, let us consider for a moment the trend in management eduction, where complex games, involving simulation and computers, are being employed as teaching devices for decision making in industrial and military activities. War games, while falling outside the scope of this paper, have progressed from their original objectives to train officers in infantry tactics and logistics to sophisticated simulation models which include technological, economic, and political factors as well as major military factors. An up-to-date, expository discussion of war gaming is presented by Clark C. Abt (1964).

As regards "business games", a vast literature is already available. Mention should be made of a conference sponsored by the Ford Foundation, which was devoted specifically to the consideration of business games as educational tools (Dill, Jackson, and Sweeney, 1962). An excellent summary (based upon one of the reports at this conference) is incorporated in a paper by Dill and Doppelt (1962, pp. 30-31):

> "In contrast to other methods of instruction, games make students more explicit about what they are doing, seeing, and hearing. Games give them quick feedback about the quality of their decicions. Games also heighten students' interest and motivation.
>
> "As a result, games may be superior to other methods of instruction introducing learning which is general and structural and not bound to specialized content or issues, which integrates the processes by which decisions are reached with the substantive issues in the decisions, and which reinforces factual material provided through earlier reading or discussions".

While the foregoing evaluation and the authors' own observations about the learning process are far from conclusive, Dill and Doppelt point out that the evidence is sufficiently persuasive to convince even the skeptics of their university faculty that the "management game" is a worthwhile innovation to the graduate curriculum.

SIMULATION OF MAN-MACHINE SYSTEMS

The use of operations simulation for the study of military systems goes back some twenty years. Among the first man-machine system experiments were those conducted at Harvard and Johns Hopkins Universities on Combat Information Center (CIC) operations, under the sponsorship of the National Defense Research Committee, Office of Scientific Research and Development. Since that time several dozen laboratories have been established for the conduct of man-machine system experiments of interest and concern to the Army, Navy, Air Force, and Department of Defense. Of course, the objectives of these experiments varied greatly--from the prediction of over-all system effectiveness, to comparison of alternatives, to the simple investigation of the result of manipulating a specific variable. Looked at another way, the experiments also were concerned with component parts of the system, namely, the hardware, the computer programs, the personnel, operating procedures, etc. Training as an objective was not the primary focus of these early experiments. However, a by-product of the experimentation in the Systems Research Laboratory of the RAND Corporation (1952-54) led to one of the most impressive and extensive training programs--the System Training Program (STP) of the Air Defense Command, U. S. Air Force.

While the original experimentation in the Systems Research Laboratory was in the nature of a scientific search into organizational behavior (Chapman, et al, 1959)--including inevitable mistakes, restarts, modifications, and development of techniques--several findings emerged which have broad implications for the study of performance of complex man-machine systems. Most important, in the present context, are the training principles which are basic to System Exercising for Training and Evaluation (SETE), namely:

1. Train a functionally complete unit

2. Simulate the real environment of the system

3. Train the system to operate under stress conditions

4. Exercise the system frequently

5. Provide the system with knowledge of results

In applying these principles, the procedure would be somewhat different in a laboratory than in the field. In the former case, the simulation of the physical environment could lead to some major problems, while in the latter case the physical environment need not be simulated since the training takes place in the operational setting. However, the task environment is simulated in either case. Fortunately, many information processing systems employ secondary or symbolic representations of the real environment (e.g., a department store inventory control maintained

through punched card records, or a ground-controlled air defense system which "sees" the actual aircraft as blips on a radar scope. In such systems it is relatively simple to create a highly acceptable simulation of the real data. It is the generation of controlled, complex training environments, making use of electronic computers, that is the unique aspect of exercising a man-machine system in a field operation.

OPERATIONAL SYSTEM EXERCISING

As noted in the preceding paper, military exercising of a team of men, multi-teams, or an entire system may be conducted in the actual working environment or in special facilities built for the purpose. The former type of program is employed primarily by the Air Force and to a lesser extent by the Army, while the latter form is employed primarily by the Navy, with the other services using it to some extent.

The development of a simulation model for training purposes will be exemplified by the System Training Program (STP) as employed by the Air Force.[1] The goal of STP is to provide the means for exercising efficiently as a team. It is not sufficient that the individual operators be trained in the operation of their respective machines, nor in the performance of their specific functions. It is equally necessary that the various individuals and units learn to operate as an integrated team with a common, or system, goal. Of course, training in the individual tasks is essential if the system is to function at all; but something more is required if the system is to accomplish its goal of successfully defending against attack. Thus, the express purpose of system training is to develop the integrated skills and attitudes which facilitate effective system operations.

This training is done in the actual operational centers with the crews using their regular equipment; for instance, a crew in a radar site uses its actual radar consoles, plotting board, telephones, and other standard equipment. Basically, only the air environment is simulated. By this means, the crews have a chance to exercise in situations which they might normally never face, if we are fortunate enough to avoid a major war.

[1] The following description of the System Training Program is taken from Harman (1964, pp. 7-13).

It is readily seen that the primary objective of STP is an elaboration of the first of the training principles enumerated above. To train as large a team as is expedient may mean a single air defense site, several sites working together, or ultimately an entire air defense system. Paradoxically, the larger or more complete the unit, the easier it is to provide realistic simulation; the more the system is cut down, the greater is the difficulty of providing adequate simulation for the smaller unit retained, as will be evident from the discussion which follows.

The second principle requires that the simulation be adequate, i.e., that it provide for all of the inputs that normally come into the system and that the choices of action normally available to the crews be provided. The accomplishment of such operations simulation involves a complex technology, and can be better understood by reference to Figure 1. This schematic, which shows the data flow in and out of a Manual direction center, was selected because of the relative simplicity of concept. Actually, the prevalent air defense system in this country is SAGE, and there is an elaborate training program for it (Rowell and Streich, 1964). However, the Manual air defense system was deemed to be more appropriate for purposes of illustration.

The crew participating in a training exercise is shown in the center of the diagram. On the periphery are indicated various real-life agencies, which normally interact with the direction-center crew, but are not included in the exercise. To provide for this link (which would otherwise be severed) a simulation team is introduced. This consists of a small number of men (with certain hardware, scripts, and associated aids) who act for external agencies which are not taking an active part in the exercise. For example, if an adjacent radar site were training concurrently with the given direction center, then they would use their normal between-site communication lines for lateral telling of information. However, when a single site is exercising, it becomes necessary to simulate adjacent sites--a task performed in a back room by an airman who has appropriate aids to make this possible. To repeat, then, the basic simulation model consists of the crew to be trained, in its normal working environment, with adequate representation of the "real world" with which it deals.

Having introduced this operations simulation model, we can trace a sequence of events through the system. Aircraft data normally come via the antenna and associated radar gear to the scopes. The inputs to the system to be trained are provided by 70mm. photographic film, specially processed after the aircraft positions are computed on an IBM 7094, and displayed through a radar signal simulator (a flying spot scanner, designated AN/GPS-T2) as blips on the radar scopes. The appearance of radar echo returns on the scopes is based upon the flight characteristics of the real aircraft and upon the actual radar coverage of the station; i.e., targets appear, fade, re-appear in accordance with the aircraft simulated and the topography of the terrain. Also, to preserve realism, ground

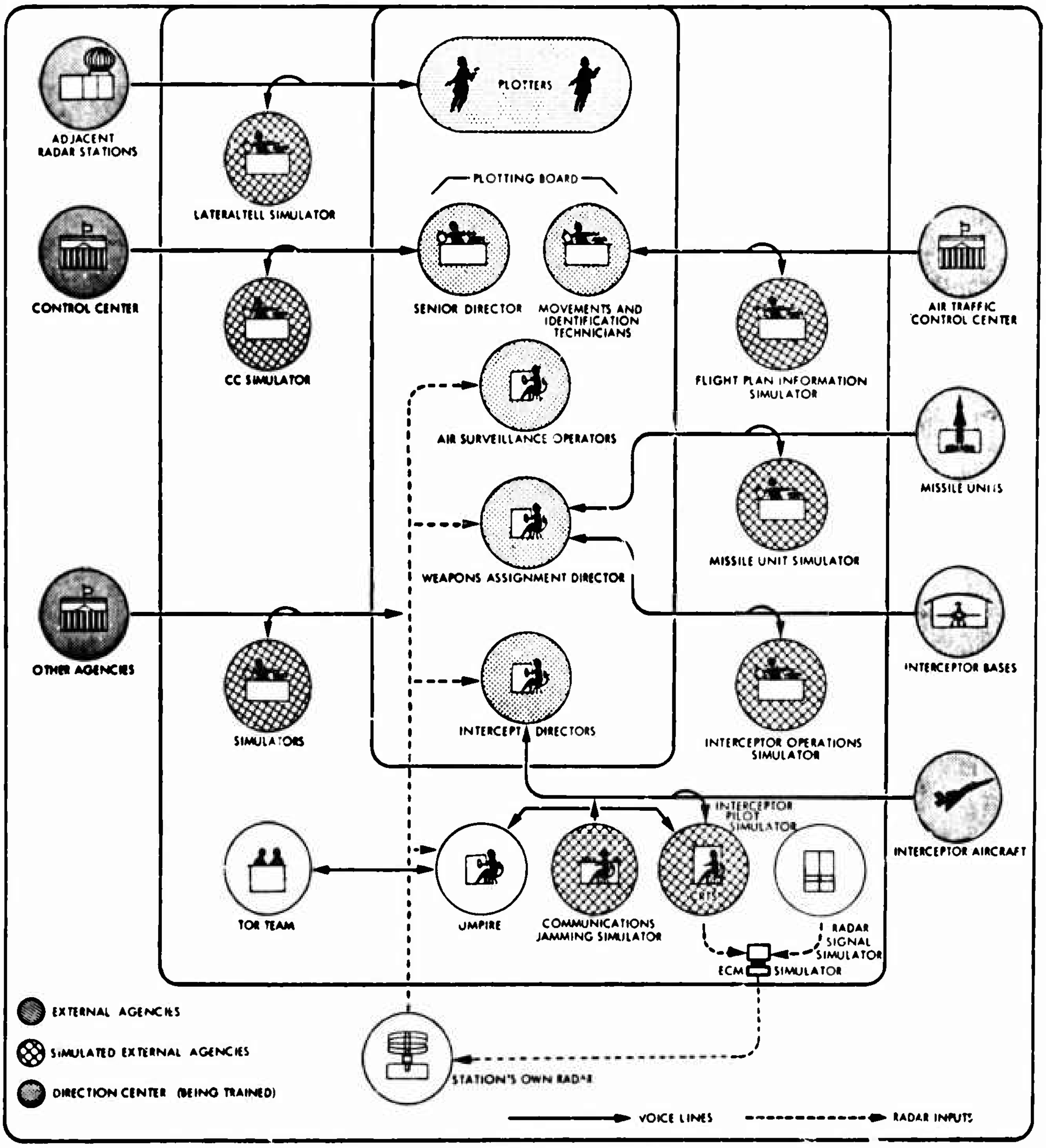

Figure 1. STP operations data flow in an air defense direction center

clutter and weather conditions are provided by a video modifier which filters out moving targets but permits large, essentially static objects to come through.

Along with the problem situation, which is planned by military officers with the assistance of training specialists and generated in the computer, certain other inputs and controls are produced by the computer. Ordinarily, the air traffic control center, or similar agency, is not actively participating in the training exercise, so it becomes necessary to simulate flight plan information for commercial traffic. A communication link is provided between the movements-and-identification technicians being trained and a "human simulator" who provides flight plan information according to a prepared script.

When the crew designates an aircraft "unknown", the Senior Director may request an interceptor base to "scramble" an interceptor fighter to try to identify the unknown aircraft. In the simulated exercise this again involves human beings in a back room who have available to them a radar target generator (AN/GPS-T4) by means of which they can produce maneuverable target blips on the scopes. An Intercept Director, undergoing training, can direct the interceptor fighter by talking via a simulated radio channel to the pilot simulator. An umpire works with the simulated pilots to determine whether the Intercept Director has positioned the interceptors properly to complete the mission.

We have now covered, briefly, the first two basic principles of SETE, namely: the training of as large a functional unit as required, and the representation of the real-life system as adequately as possible. The next principle requires that the system be trained under stress conditions. To develop and maintain the system at a high level of proficiency, it must be trained to handle effectively a variety of stress situations. Simulation of the system environment permits control of the kinds of air situations introduced to the crews. STP problems can be produced that contain heavy traffic loads, realistic invader attacks, electronic countermeasures, battle damage, and other stress situations. These situations are not encountered in the day-to-day routine of air surveillance and are difficult, if not impossible, to obtain during peacetime.

The principle of frequent exercising is, of course, rather obvious. Operational personnel require continual practice in dealing with a variety of air situations if they are to develop and maintain flexibility in the use of system skills and procedures.

However, realistic simulation and frequent exercising, including stress conditions, will not insure improvement in crew performance. The missing ingredient is covered by the last principle: provide the system with knowledge of results. Therefore, during a system-training exercise, a team of observers with detailed knowledge of the problem content objectively records crew actions. This function is indicated in Figure 1 by the TOR (Training Operations Report) team. Immediately following an

exercise, a report of performance is presented to the crew, which examines its actions, identifies its operational difficulties, and works out ways to improve system performance. This closing of the loop--this feedback to the crews of the results of their actions--is primarily responsible for the effectiveness of their training. In their debriefing the crew knows precisely what the air situation was--if need be, the film could be rerun. With strict control of the data, there is no question as to the precise location, altitude, and speed of a plane at any given time. In addition, the TOR team provides exact and accurate feedback of the actions taken by the crew. This type of control is practically impossible to attain in a live environment.

The foregoing illustration was presented in considerable detail not only because it was easy to do so, since we have been intimately associated with STP from its beginning, but also because it represents a tried and proven program of training by simulation. Again it should be noted that in the Manual air defense system, used as an illustration here, the computer is involved only for the creation of the simulated environment. In the corresponding SAGE system of air defense, the computer is not only used for the preparation of problem materials but also replaces the human observers in the TOR and Umpire functions.

Before leaving the basic illustration of operational system exercising, it should be pointed out that there are several echelons which may be included in the system being trained. At the lowest level is the single radar site or SAGE Direction Center, but most exercises include many crews at different locations, and at several echelons, who normally work together. Thus, an entire division may exercise at one time and there may even be multi-division exercises. Finally, in a nation-wide exercise, including every echelon and every service, as many as 6,000-8,000 personnel have been trained at one time.

In conjunction with the SAGE air defense is the new Back-Up Interceptor Control (BUIC) system. This is one of the first major military programs in which planning for training was incorporated from the very beginning of the system development process.

The system exercising of BUIC will be quite similar to that currently employed in SAGE STP. The central computer is a Burroughs 825 (designated AN/GSA-51). The system model for training would be a NORAD Control Center (NCC) with five radars feeding into the computer. Of seven consoles in such a system, six would be used for training operational positions while the seventh would serve the simulation supervisor.[2] Three pilot simulators can operate from this one console. An interesting aspect of the BUIC system, and hence also of the simulated model, is that any one of the six consoles can be designated for any operator position, e.g., Senior Director, Air Surveillance Officer, Weapons Director.

[2] Corresponding to the Training and Battle Simulation room in the SAGE system.

While the basic training problem materials for system exercising in BUIC are prepared on a central computer, this being a computer-based system, there is also the capability for field site production of training materials. The central computing facility (at SDC) can prepare training problems separately for the Air Force Manual air defense system, SAGE, BUIC, and for the Army air defense system; furthermore, it can prepare compatible problems for all of these systems exercising jointly.

The Army Air Defense Command (ARADCOM) also conducts a program of operational system exercises. This is a variant of the Air Force STP which was first tested in 1959 on a very modest scale at the Fort Meade Missile Master air defense complex and now includes all Missile Master and certain selected BIRDIE (Battery Integration and Radar Display Equipment) sites. This program has the express objective of developing integrated skills and attitudes for effective system operation in an AADCP (Army Air Defense Command Post). The operation of STP at a Missile Master AADCP parallels the schematic representation of Figure 1 to such an extent that it is not worthwhile showing it separately. Of course, the positions in an Army Missile Master unit are different from those in an Air Force Direction Center, and some of the external agencies with which they interact are distinct, but conceptually the model is very similar.

One important difference is the use of an electronic fire unit simulator in lieu of active battery participation. With the aid of two human beings, the battery simulator responds to the actions of Tactical Monitors (undergoing training) by simulating appropriate actions of a fire unit and determining whether the engagement is "effective" or "ineffective", on the basis of a kill probability table.

While the Army STP is directed primarily at the AADCPs, training of operations personnel at the integrated fire control area of some NIKE fire units is provided by means of another simulator (AN/MPQ-36). This device provides simulated radar inputs for training in the operational phases of acquisition, tracking, and commitment. It permits the simulation of six airborne targets, chaff, electronic jamming, and one NIKE Hercules missile. A scoring system is also provided to aid in evaluating crew proficiency. Another device (AN/TRQ-21), currently in production, is designed to provide training of personnel at HAWK fire units in a manner similar to that at NIKE units. Finally, the Army is planning a multipurpose radar signal simulator (15E9 which would provide coordinated simulated video to the AADCP and the fire units; and with the aid of a digital computer, it would have the capacity for recording and evaluation.

It should be noted that only because an Army Air Defense Command Post deals with second-order data is it relatively easy to introduce operations simulation and to conduct system training. In the more conventional Army activity--essentially face-to-face combat--it is much more difficult to design appropriate operations simulation for training. There are, of course, many examples of "hardware" simulators but few of them have been conceived and employed primarily to facilitate training in a system context.

Still another use of operations simulation is being carried out by the Tactical Air Command (TAC). The tactical air control system is charged with such missions as counter air attack, assault air lift, close air support, interdiction, air defense, and reconnaissance. To provide training for such missions while enlisted men and officers are in the United States (under TAC), awaiting deployment by the Strike Command (STRICOM), simulated exercises are employed in addition to STRICOM live exercises. A system training exercise at the lowest level of operation corresponding to the air defense model of Figure 1 includes the Control and Reporting Center (CRC) and Control and Reporting Post (CRP). Training is going on at these levels right now while plans to include the next higher level, Tactical Air Control Center (TACC), are under way. A functionally complete unit might involve a single TAC encompassing two sets each of two CRPs under one CRC. The TAC simulated exercises may require mythical ground environment, e.g., locations of radars and air bases, in addition to the real geography. The simulated air environment for such exercises is generated by the same means and employs the same technology as the Air Defense STP.

SYSTEM SIMULATORS FOR EXERCISING

In addition to the operational system exercising discussed above, there are many specialized simulators employed to enhance the performance of military systems. Responsibility for and management of the design and development of such training simulators for the Air Force, Army, and Navy are vested in the U. S. Naval Training Device Center (NAVEXOS P-530-2) and a Special Training Devices Program of the Air Force (AFR 50-19, 1962).

In general, the military, simulator-based training programs are not conducted in the normal working environments but in specifically built facilities. The representation of the physical layout must be functionally close to the real physical environment; however, each piece of equipment need not be replicated if its operating characteristics can be simulated by some more economical means. Of course, the task environment is simulated whether the training takes place in a laboratory or in the field.

A major training program of the Navy is conducted at the Naval War College at Newport, Rhode Island, using the Naval Electronic Warfare simulator (NEWS). This facility became operational in 1958, some dozen years after its conceptualization by the Navy. In 1945 the Navy received a Combat Information Center (CIC) Trainer to assist in the shore-based training of CIC officers and associated personnel. Shortly after that, the Naval War College requested the procurement of a tactical trainer or system for the purpose of simulating warfare, incorporating more features than the CIC trainer. The system was originally designated as an "Electronic Generator and Display System" to avoid confusing it with trainers used to teach individual and team skills in special functions. Subsequently, its name was changed to "Electronic Maneuver Board System", and finally to its present designation, NEWS.

To appreciate the role of the NEWS in the Navy war game program, it should be noted that it is one of two major parts of that program, the other being the Computer Analysis Program. While operations simulation is employed in the NEWS, symbolic simulation is employed in the Computer Analysis Program to obtain statistical measures under varying conditions. In this way the Navy exploits the different forms of simulation in ways best suited to the objectives of training future leaders, planning, comparing tactics, and comparing different weapons systems.[3]

The NEWS is a means of conducting a maneuver board problem with the assistance of electronic equipment. It is designed primarily for tactical training by the Naval War College and the Fleet Commands. The physical facility occupies about 35,000 square feet of floor space, consisting of many small rooms which serve as Command Centers, an auditorium-type umpire area, and various equipment and control rooms. The NEWS provides extensive communications systems and force radar presentations; it indicates course, speed, and altitude for aircraft or missiles. The commander, his staff, and individual unit commanders are located in the various command centers. The command centers realistically simulate a Flag Plot, unit command center, or an air tactical command center. From his Flag Plot the commander observes and evaluates the situation as it develops, exercises control of his forces, and tests the soundness of his plan.

The operations simulation provides for the employment of a total of 48 maneuverable forces (e.g., an individual ship or aircraft, a task force, a shore installation, or an entire attack carrier striking force). The forces are moved and fought electronically by commanders located in combat information centers containing radar scopes, fire control panels, radio phones, and all other equipment needed to enable the commander to maintain control over the forces under his command. At the start of a war game, 24 forces are assigned to each side, comprising ten command centers. As the game proceeds, interactions of forces occur. Results of these interactions are determined by umpire observations assisted by a programmed analog-digital computer stored with weapon characteristics and target damage data. During engagements, the computer determines hit probability (based on weapon characteristics and range to target) and computes incremental damage per hit based upon target vulnerability to the weapon being employed. The computer determines the damage and automatically introduces a reduction of maximum speed and weapon effectiveness of the target force when appropriate. Rapid calculation of results of interactions enables the battle to progress in real-time as well as to reflect the progressive capabilities of the forces at any given moment during the action.

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[3] For a more detailed description of the Navy war games program including the contrast of the Computer Analysis Program with the operation simulation in the NEWS, see Davis and Tiedeman (1960).

Upwards of a hundred participants are required to play a full-scale war game on the NEWS. The NEWS system has been used to determine the areas that require intensive examination in planning an actual fleet exercise, and it has also been used to examine, by replay, an actual exercise that has already been conducted. The NEWS installation "has provided the U. S. Navy with an immeasurably valuable vehicle on which to further the education of its officers and to provide them the opportunity to gain significant combat command experience that is not available elsewhere in various aspects of modern naval warfare" (U. S. Naval War College).

The Navy employs many other simulators for training--ranging from individual operational flight trainers to team and multi-team trainers, and ultimately to very large system simulators for exercising entire task forces. Every one of these trainers employs some kind of computing device--analog, digital, or hybrid. Perhaps mention should be made of one of the latest devices which is of the order of magnitude of the NEWS. This is the ASW Coordinated Tactics Trainer which is going into operation now at the ASW Tactical School, Norfolk, and another version of which for the Fleet ASW School, San Diego, will be operational in about two years. This system simulator is housed in a structure of some 30,000 square feet and includes a special purpose digital-analog computer (built by Lockheed). There is provision for 18 ship CICs with 4-8 men in each, 1 carrier, 1 Flag Plot, and 16 aircraft (patrol, ASW type, or helicopters) as well as for numerous targets. In a full system exercise some 200 men may be undergoing training, requiring upwards of 35 instructors and additional support personnel. A training problem may last from three hours to an entire week. In addition to the crews exercising on the simulator, other personnel may be trained vicariously by observing the projection of all actions as they are recorded. The training philosophy here permits the instructors to interact with the crews during training as well as in debriefings following the exercises.

An interesting and quite different training program is being conducted at the Spacetrack Center of the Air Force Air Defense Command at Colorado Springs. While this system was conceived as a research and development effort, it is, in fact, operational and includes training as one of its objectives. Roughly stated, the mission of the Spacetrack system is to keep track of man-made satellites around the earth. To assist in this task, an IBM 1620 computer is employed for basic card handling while a Philco 2000 computer is used for the integration of data. Of the numerous reports coming into the Center most are associated appropriately with previously determined orbits. However, new readings which are non-routine go to a Duty Orbital Analyst (DOA) for resolution. From these new inputs, and perhaps such information as intelligence and domestic pre-launch data, he attempts to deal with such problems as setting up domestic-launched satellite orbits, foreign-launched satellite orbits, debris separation and prediction, and lost satellites.

While the Air Defense Command had several Duty Orbital Analysts, they felt the need for more DOAs for Spacetrack and for other systems under

development. Hence, an 11-week course for the training of 30 analysts was conducted consisting of the following parts:

1. Classroom instruction including courses in celestial mechanics, aerospace ground environment, detection, recognition and tracking, introduction to programming and data processing equipment, and Spacetrack program systems

2. Part-task exercising program in which each trainee was given discrete segments of a DOA orbital determination problem

3. Whole-task exercising in which a team of five trainees worked together, using the computer as necessary

The training materials used in the part-task and whole-task situation included simulated inputs on cards and appropriate fictitious data file tapes. This example exhibits an important combination of classical training procedures combined with operational system exercises.

Moving one step further from direct consideration of national defense, there are a number of plans under way for exercising man in aerospace systems. An investigation of a variety of simulation techniques for aerospace crew training was recently completed at the Behavioral Sciences Laboratory at Wright-Patterson Air Force Base (AMRL-TDR-63-100).

An operations simulation effort is being developed to support the integrated training programs for the two major aerospace programs of Gemini and Apollo. Based on the actual Integrated Mission Control Center (IMCC), the simulation model of the ground support system is planned to include the following:[4]

1. The Gemini and Apollo mission simulators

2. Two simulated remote tracking stations, which fully represent the actual remote station configuration except for acquisition and tracking systems

3. Eight dummy remote stations, with communications equipment only

4. A ground support simulation computer (IBM 7094) for the production of simulated radar tracking data, simulated telemetry output of Agena and its Atlas launch vehicle, and for the control of exercise sequences and network functions

5. Simulation Controls Consoles for the control of certain aspects of the exercise and for the analysis and evaluation of flight controller performance

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[4] For a more complete description of the simulation model see Ruetz and Dennett (1963).

6. Provision for appropriate interface between operational and simulated components

The Integrated Mission Control Center along with the simulation system will shortly become operational. The task of training flight controllers and developing mission rules for Gemini and Apollo is the specific objective of this simulator. The first mission supported by training in this new system is expected to be a Gemini flight in late 1964.

While several of the major training programs employing simulation techniques have been presented, there is no claim that this discussion is exhaustive. Limitation of space made it necessary to exclude many simulators employed by the Army, Navy, and Air Force for team training. The selection of the particular systems was made with a view to explicating the operations simulation technique used in exercising crews synthetically either in their actual operational setting or in specially designed simulation facilities.

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CHAPTER 19

M. STEPHEN SHELDON

EVALUATION OF TRAINING IN A SIMULATED ENVIRONMENT

All military training programs are continually being evaluated. This evaluation generally takes the form of a value judgment made for the commander of the crew by the military crews who are being trained. Only in a relatively few instances is the training evaluation based upon hard measurement data, data recorded in a well-designed and constructed applied research context. Notable examples of such training evaluations are the assessment of flight trainers, e.g., the Ellington study (McClelland, 1954), a study by Siskel and Flexman (1963), and many of the naval maintenance programs (SPECDEVCEN 269-7-100). Training of small crews has also been empirically evaluated (Sheldon, 1964), and the evaluation of system training in a large military system has in one instance been reported (Rowell, 1962). However, there is no indication that system training packages for large computerized military systems have ever been subjected to empirical, quantifiable, communicable evaluation.

Military psychologists, human factors personnel, and military units seldom question the value of a training program. For these groups training has certain values. They accept the clinical type of evidence which "seems to indicate" or "appears to result in" more efficient performance of the system.

In recent years military services have taken cognizance of the role of evaluation in the system's training program. The establishment of the Personnel Subsystem concept, which includes System Exercises for Training and Evaluation (SETE) (AFR 30-8, 1964), forces a distinction between exercising and training. That exercising a military system results in training must be demonstrated. This can be done only by showing a measured improvement in crew performance as a result of the exercising. In this paper, two training evaluation problem areas will be considered. The first deals with the development of measurable criterion variables to assess crew performance empirically. The second concerns the situational variables which must be part of the simulated exercise in order for meaningful measures to be extracted for evaluation.

THE CRITERION VARIABLES

A precursor to the development of criterion variables is the differentiation between "measurement and evaluation" in a military setting. Evaluation implies the stating of a value judgment concerning the effectiveness of the military system. Measurement incorporates the use of organized and quantifiable observations. The value judgment should not be made by a civilian contractor, a civil servant, or any outside military agency. The value judgment concerning the effectiveness of the military crew must be made by the commander of that crew. It is the function of the military psychologist to supply the evaluator with measurement data, i.e., the results of organized observations and techniques for data collection so that the value judgment concerning crew effectiveness is based upon reliable and valid evidence.

In developing criterion variables, one must answer these questions: "What should one look at? What kinds of data are easily obtainable and meaningful for judging the worth of the training program or the combat-ready status of the crew?"

The first step in the development of measures for evaluation should be the statement of the over-all system objectives in operational terms. Depending on the military system involved, this can be a simple or a very difficult task. As an example, consider an air defense system. For such a system one can say that the over-all system mission is to protect the ground targets in a defined area of responsibility. (This, of course, does not tell the whole story; one could add other less imminent objectives such as communications with higher headquarters, warning adjacent areas of potential threats, etc.). Such a generalization of system mission is a far cry from an operational definition. However, if one can accept the assumption for an air defense system that the closer the hostile airborne object is allowed to approach a ground target, the higher will be the probability that it destroys the target, one can operationally spell out the major system mission. The number of nautical miles between the hostile object and the ground target permits accurate and quantifiable measurement. This example is used only to illustrate how a system mission can be defined in terms of a continuous measurement variable. A complete knowledge of the system is necessary before stating such an operational definition. Superficial familiarity with a given military system might lead to the acceptance of highly questionable criterion variables. For example, the number or proportion of enemy vehicles that are destroyed is frequently not relevant to a system mission. If the enemy vehicle has, in fact, accomplished its mission, its destruction is inconsequential.

Once an operational definition of the over-all system mission has been established, one has answered the question concerning what observations should be made. On the basis of such observations, the judgment about system effectiveness and about the worth of the training program can be more accurately established. However, for follow-on training to

be meaningful, there must be some diagnosis of system errors that were made in the accomplishment of the system mission. The operational definition of the over-all system mission must be supplemented by measures that are appropriate to evaluate subsystem and functional-unit skills. For example, in air defense there are five basic tasks that must be performed in accomplishing the over-all system mission. These are detection, identification, tracking, commitment, and guidance. The tasks are sequentially ordered, i.e., identification can not take place before detection, etc. To diagnose system difficulties, one could take time and accuracy measures on each of these five tasks and make a judgment about which tasks were most in need of training.

It has been claimed that evaluation in a simulated environment "allows the experimenter to maintain stimulus control" (Davis and Behan, 1962). When one is referring to a computerized military system, this statement is fallacious. One can "control" the stimulus or input only to that part of the system which initially processes data. For most military systems this is a detection function. If one is to measure the performance of other subsystems or functions, the "stimulus control" is missing. This alters considerably the meaning of such classical measures of performance as time and accuracy. Such measures need to be carefully qualified. The first qualification stems from the sequential nature of system tasks. One can not penalize a weapons team for failing to intercept a hostile aircraft if the aircraft is not detected, identified, and accurately tracked. The second qualification for time and accuracy measures is concerned with the nature of the system. There are occasions when delaying an action is a well-thought-out decision. For instance, when one is concerned with economic use of weapons and armament, a weapons director might intentionally defer action on a known hostile. This would considerably degrade his time and accuracy score, though he is, in fact, behaving in the best possible way to accomplish the over-all system mission.

When one derives the submeasures to evaluate system performance, procedures should be incorporated which will allow for a test of the relationship between the submeasures and the over-all system criterion variables. Such procedures have been attempted for the SAGE air defense system (Sheldon and Hillis, 1964). All measures used to evaluate crew performance in a simulated environment were collected during a series of specially prepared simulated exercises. Each of the variables which was considered relevant to assessing functional units and subsystems was correlated with over-all system measures. Further, inter-correlations among variables were computed and the resulting matrix factored. The results of this study recommended the deletion of those measures which did not have a significant relationship to over-all system performance. They further recommended the inclusion of a smaller number of systematically obtained observations to make judgments about crew performance.

The development of criterion variables for system measurement is not an easy task. Because of the nature of modern military systems, there is little parallel between such procedures and classical psychometrics. The

classical procedures for estimating reliability, validity, and internal consistency are meaningless in the development of system measures. The system represents an N of one. In terms of a psychometric approach, there are zero degrees of freedom. Further, intersystem comparisons become all but meaningless because of the differing environments, equipment, and system missions.

It has often been recommended that responses of crews be used to develop measures for system measurement (VanAlbert). In a large computerized military system, the data collection or recording can itself represent a major problem. If, as suggested in an earlier section of this paper, training requirements are developed concurrently with the system, space should be allotted in the operational computer for an accurate recording procedure. If this is accomplished, one can record everything that the computer "knows". A practical criterion for the development of measures is to use only these (computer) data to develop measures for crew performance. If one is forced to resort to a great deal of human observations and ratings, the factors of practicality, economy, and reliability interfere with development of meaningful criterion variables.

In discussion of the criterion variable four points have been made.

1. Derive an operational definition of the over-all system mission.

2. Break down the system mission into smaller, measurable components which permit the diagnosis of system difficulties.

3. Check to insure that the submeasures relate to the over-all system mission.

4. Use the operational computer to assist in system measurement and evaluation.

SITUATIONAL VARIABLES

When one is measuring crew performance in a simulated situation, the measures can be greatly affected by how one simulates the enemy and the environment in which the battle is being waged. The variables which define the parameters of enemy action and the battle environment are situational variables.

Such elements as load, rate of enemy penetration, and noise can be manipulated so that a crew can appear to perform very well or very badly. Consequently, when measuring the performance of the crews, the simulated environment is a major factor. Judgment of the crew's combat readiness in a simulated environment will be determined by the difficulty of the problem presented.

The problem of the situational variables can be summed up by asking the question, "What should be simulated when one is evaluating a military system?" Gebhard and Hanes (1965) answer this question by saying "... only those elements that are deemed relevant after careful study of the situation...." There can be no argument about this. However, one is not advised on how one determines relevance. There are definite steps which must be taken to decide which elements of the battle are worth simulating.

The first step is a stress analysis study. The outcome of such a study would permit a listing of the kind of events which tend to degrade system or crew performance. In most cases such a list would be completed by a careful system analysis, together with a knowledge in depth of the potential enemy. It is the job of those concerned with training to be completely familiar with the system with which they are working as well as with the ability of the opposing system to interfere with its functioning. One must not only present the military system with targets at which to shoot, but must also present it with all the stress events, all the countermeasures, that the enemy is capable of impinging on the system. When appropriate, this would include the effects of sabotage, sensor outages, weapons aborts, and much noise. If one omits any interfering element that the opposing system is capable of producing, all measures taken in that simulated situation are questionable. Furthermore, training in an environment with such omissions teaches crews to ignore or not expect important elements of a real battle situation, consequently doing more harm than good. Our crews may be lulled into thinking that the enemy is as benign as this false representation. Instead, we know that in the real battle the enemy will present as malignant an environment as he can muster.

Once the relevant situational variables have been specified, it is important to determine the relationship between these and the measures of crew performance. If such relationships can be empirically computed, such as with multivariate analysis, the norm or expected performance of a crew can be predicted.

For a system evaluation in a simulated environment, the relevant situational variables are those which will influence the measures we take. The <u>reality</u> of the simulated presentation is an irrelevance. It is frequently the case that one can not face the military crew with the real elements of a battle. However, a careful analysis will permit specifying the tasks which must be performed by the crew. Then, our job is to present the crews with those <u>effects</u> of reality which contaminate the environment so that crews are faced with problems that are at least as difficult as the <u>worst</u> that the enemy is presently capable of producing.

Most of the military systems exercise to some degree with "live" missions. We have SAC fighting NORAD, the Red army fighting the Blue army, and the American submarines fighting the Naval Task Force. A superficial consideration of such exercises would lead to a judgment that this represents those real elements of the battle situation which

hamper the various military systems. We immediately can see that, because of safety precautions and lack of control of inputs to the system, the artificial reality of "having someone out there" does less for training military crews to face a real battle than a good simulation program.

A good simulation program is one which presents the crews with situations requiring all the decision-making, action-taking, and communication behavior that the real war will require of them, omitting only the anxiety which the real war would present. Further, such a program should permit accurate, quantifiable, and empirical measures upon which to base the evaluation of the crews and the training program.

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PART IX

INFLUENCE EXERTED BY U. S. MILITARY PERSONNEL AND SYSTEMS ON ATTITUDES AND BEHAVIORS OF INDIGENOUS PEOPLES OVERSEAS

INTRODUCTION TO PART IX

The three chapters in Part IX deal with research on influence exerted by U. S. military systems and personnel on attitudes and behaviors of indigenous peoples overseas, with emphasis on use of propaganda, intercultural communication, civic action programs, and other non-violent techniques. Treatment of this topic was organized by Dr. Theodore R. Vallance, Special Operations Research Office (SORO), The American University, Washington, D. C. Dr. Vallance is the author of Chapter 20 in which he restates the functional objective of mediating change in foreign cultures in a communications framework, and cites such psychological factors as mutual sensitivity to attitudes, values, and goals, and specific knowledges of particular countries and peoples as needed for more effective cross-cultural communication. Chapters 21 and 22 were contributed by Dr. Alexander Askenasy and Dr. Lorand Szalay, both of SORO.

Dr. Askenasy traces the concept of psychological operations back through the equivalent activities in other wars--psychological warfare, propaganda, even the politics of Clausewitz--to the present terminology which embraces both military and other actions directed specifically toward changing the attitudes and behaviors of foreign populations. He thus avoids viewing psychological operations as a minor adjunct to traditional military activity, seeking rather to present a wider field which may bring military and psychological thinking closer together.

In this view, military, political, economic, and psychological actions are all forms of communication, processes through which intentions are conveyed. He stresses need to question the implicit assumptions we make about our own motivations and those of the enemy. Placing psychological operations in the current world environment of "little wars", he cites the necessity of calculating the effect the alternatives we present or imply may have on the enemy's decision to continue war or to accept our alternative. In conclusion, Dr. Askenasy lists various lines of research which could help the military maximize the psychological effectiveness of specific actions.

Dr. Szalay explores the distinctive features of intercultural communication. From a summary of the situational variables and the functional principles which distinguish intercultural communication from intracultural communication, he proceeds to the contrasting research requirements of the two kinds of communication:

"No persuasive intercultural communication is possible unless the communicator is knowledgeable about the nature and extent of differences between him and his audience....Research in support of intercultural communication must concentrate on a specific foreign culture and explore definite categories of verbal-cognitive characteristics and value orientation."

CHAPTER 20

THEODORE R. VALLANCE

PSYCHOLOGICAL ASPECTS OF SOCIAL CHANGE MEDIATED THROUGH THE INTERACTION OF MILITARY SYSTEMS OF TWO CULTURES

Parts IX and X of this volume are concerned with psychological research on the influence exerted by U. S. military personnel and systems on the attitudes and behavior of indigenous peoples overseas. Specifically, we are dealing with the effects of the military man's behavior on relationships--hopefully compatible with U. S. policy objectives--with the peoples of other societies.

A second aspect of the problem is communication with foreign peoples via "postures" of the United States toward the dominant forces within foreign governments--strategic moves, treaty overtures, weapon systems developments. Communication of this kind is the topic of later chapters in this volume.

Our approach is oriented toward the interests, research competences, and accomplishments of psychologists in matters of communications: communications that are addressed to and occur mainly between non-heads of government, communications via mass media, and communications between as few as two people of differing cultural backgrounds, with or without community of basic objective.

But first it would seem appropriate to set some context for our presentations.

A fair amount has been written lately on the shift in emphasis from hardware-based strategies to strategies based on understanding and control of social processes in the total recipe of U. S. operations in the current cold war. A symposium at a previous convention of the American Psychological Association (Vallance et al, 1963) suggested nation-building research as a new role for the military. Ithiel Pool (1963), a political scientist, has written persuasively about how the nuclear weapons stalemate has led to a shift to smaller wars and the consequent requirement to understand, in order to control, insurgency or internal war which is fast becoming the mechanism for carrying on conflicts between East and West. Similarly, a review by Charles Windle and myself (1964) concluded recently that the shifting currents of foreign policy, and the Clausewitzian uses of the military arm as an extension of policy, will lead to interesting revisions in objectives, methods, and content of psychologists' research within the military.

We forecast a trend away from emphasis on human components of hardware systems to emphasis on human components of social systems, and an increase in the study of human interaction and communication across cultural boundaries. I believe that evidence is accumulating which will show that this forecast was essentially correct.

Rather than develop at length the arguments that make up the context for these papers, I will simply summarize by using an over-simplified triple entendre under the heading of "The Minds Race," with credit again to my colleague, Windle.

For at least a decade after World War II, the United States and Russia were involved in an arms race, competing in technological development for supremacy in the most massive use of force to date, nuclear war. Now, it appears, the arms race has decreased considerably in intensity, and is being largely replaced by what may be figuratively called a "minds race." Instead of pursuing bigger and better armaments ("arms"), we are now competing in pursuit of what is loosely known as the "hearts and minds of the people." The reasons for this shift were several; among them:

1. The arms race had tired both runners. It began to appear that there might not be any finish line; worse yet, if the race were to be finished, there might be no one left to record the winner.

2. The nuclear stalemate had led to multipolarity within both East and West, with new possibilities of alignment. Non-nuclear ways of dealing with new power centers were required.

3. The shift from aristocratically-led to popularly-led governments was producing nationalistic ideologies which competed, thus increasing the importance of propagating a good and stable "image"--or ideological story--to foreign populations.

4. The aspirations of the peoples of emerging nations were leading to insurgency against governments which failed to realize these aspirations. These aspirations remain a convenient vehicle for foreign powers to manipulate for their own purposes--one reason why internal war has been so frequent of late.

5. Internal war is based upon the power of the people, when they are properly supported, to resist or depose an unpopular government. Experience in Malaya, Indochina, and many other places shows just how potent "the people" are. Consequently, the cooperation, goodwill, and compliance of a people is always a primary goal of both insurgents and counterinsurgents.

Since there are conditions already existing which seem to indicate that most of the major conflicts in which the United States is likely to be involved, either directly or obliquely, in the decade of the 1960's, will be internal wars, this country has need to know

how to prevent insurgency or how to counter insurgency wherever doing so would be in the best interest of this country and of the Free World. As the causes of insurgency seem to lie in the hearts and minds of the people, we had better "get with" the competition and learn how to affect hearts and minds.

This description of the problem as "hearts and minds" is admittedly a bit too common sense for a convention of psychologists. It is also inaccurate--not in the sense that hearts do not emote and minds do not exist, but rather in the oversimplification of the nature of attitudes, behaviors, and roles of individuals and groups in societal conflict.

Rather than try to state again the opportunities and obligations of psychologists in the minds race, I shall revert to the objectives of the present part of this symposium, and more specifically, my own topic: "Psychological Aspects of Social Change Mediated through the Interaction of Military Systems of Two Cultures."

In view of the current deployment of U. S. military forces as part of U. S. Country Teams in over 58 countries, we must recognize that the U. S. military establishment has a new functional emphasis: mediating changes in foreign cultures. No longer does the military rely on enforced establishment and management of a set of institutions of production, distribution, and government; it now cooperates with other members of U. S. Country Teams in influencing the course of development in many foreign lands. One of the more manifest features of the situation is that this influence is ministered primarily through interaction with, and consequent effects on, the indigenous military institutions, contrasting sharply with the more traditional case. In early post-war Germany and Japan, for example, the U. S. military, as the agency of an occupying power, dealt directly with existing instruments of authority and other civil institutions.

The U. S. military is now engaged (in most places) in a peaceful relationship with the military of friendly countries, usually carrying on training or other advisory functions, and involving itself to some degree in incidental and occasionally planned contact with the civilian populace.

Let us now turn to some of the psychological aspects of this particular set of culture contacts, and consider what research might be required to understand the military relationship and its role in introducing changes into other components of the society.

To understand the nature of contact between military institutions--indigenous and foreign--and a society would require a considerable analysis of the role of military institutions in the society. How do the two military institutions compare with regard to their influence on the nation's economy, or with regard to their role in political

affairs at the national, provincial, or village level? How are they perceived by the local citizenry? As friends and symbols of national strength, or as sycophants and symbols of oppression for whatever regime happens to be in power? How do members of the military institutions perceive themselves and the roles which they play in local and national affairs, both political and economic? What are their own expectations of how their roles are perceived by their countrymen?

The factors implied in these questions will have some effect on the working relationship that can be established by the U. S. military with indigenous forces, and will influence to some degree results of a U. S. military aid program.

Clearly, a study of these problems requires the integrated skills of sociologists, political scientists, and social psychologists. Some sociological and political studies have been made, but so far psychologists seem to have given relatively little specific attention to the problem. Morris Janowitz' recent book, The Military in the Political Development of New Nations: An Essay in Comparative Analysis (1964), and his earlier work, The Professional Soldier (1960), which deals mainly with U. S. military institutions, together suggest the outline of a data base for drawing such comparisons. John Johnson, a Stanford historian, has produced some additional data suggesting the influence of regional and family backgrounds on the attitudes which members of military forces of several Latin American countries hold in relation to their countries' political and economic institutions. Books by Johnson (1958, 1964), Finer (1962), Lieuwen (1960, 1964), Pye (1962, 1963), and others have dealt with the role of the military in the developing nations; and several studies currently under way within SORO and several Latin American, Middle Eastern, and Asian countries should supplement our present body of information considerably.

It would be quite valuable were the data from these studies to be analyzed for clues to self-perception (along the lines suggested by my earlier questions) and compared with similar analyses of U. S. military personnel. Only one study now being conducted, to my knowledge, specifically addresses psychological aspects of the problem within a specifically military context (Froelich).

Casting the problem in a communications framework, specifically one which focuses on cross-cultural (not comparative) communication, I come to this particularized question: How much and what knowledge must a change-agent have of the social structure, value systems, characteristic attitudes, culture traits, etc. of another culture in order for him to be a successful inducer of acceptance, by a member of that culture, of whatever it is that the change-agent wants him to accept? Also, and conversely, how much knowledge and what knowledge of the change-agent's culture should the potential changer have (or be caused to have) in order for the interchange to be effective?

(In using the term "knowledge" here, I include attitudes, empathies, and empathetic skills, in addition to factual or statistical knowledge of one another's persons and cultures.)

It is widely accepted that good communication, under almost any circumstances, fundamentally derives from communal understandings, intentions, attitudes, motives, background, and the host of factors itemized in the literature on perceptual processes seen as active in rumor, propaganda, and other forms of social intercourse in which communication is critical. Hopefully, through better understanding of these factors, we may at a later time suggest ways of improving the efficiency of the communication process.

To find what psychologists have been doing in the past several years that might aid such understanding, I made a brief survey of the literature. The answer seems to be "very little." And in terms of an effort to analyze the problem in the general terms in which I have stated it, "practically nothing." There are, however, some noteworthy beginnings.

A fair number of studies have been reported in psychological journals on the effects of foreign experiences upon various groups--most often student groups in some foreign land. [For examples, see Blood and Nicholson (1962), Kelman and Bailyn (1962), Seth (1961), and Zazonc (1961).] Usually, these studies have described and analyzed the attitude changes that have taken place, but they have not delved systematically into the determinants of the changes. Their main contribution, therefore, has been to increase the amount of case material for later interpretation or other heuristic purposes.

On behalf of the Peace Corps, Spector and Preston (1961) produced an analysis of conspicuously successful and unsuccessful incidents of interpersonal relations. The analysis dealt with useful behavior patterns and specification of goals that are subordinate to the objectives of the interchange (develops and maintains friendship and goodwill, motivates others, etc.) and did not attempt to specify the psychological processes whose better management would lead to better operations.

A yet-to-be published study by Anita Terauds (1965) of specific instances of intercultural communication contains some interesting suggestions relative to the dependence of communication effectiveness on knowledge of local conditions and needs, as well as on the skills, theoretical knowledge, and attitudes of the participants.

Leonard Doob's book published in 1961 analyzes 12 variables that seem to affect communication critically. He illustrates these variables by reference to several sub-Saharan African countries. Several of the variables he cites are psychological in content and deal with the familiar questions of perception and motivation--of both communicator and communicant-- as well as with the cultural context of the communication.

Doob's observations in Communication in Africa: A Search for Boundaries (1961), when combined with D. C. McClelland's study of The Achieving Society (1961), which includes data on some African societies., suggest a way of looking at the processes of cross-cultural communication to see what useful research might be done programmatically by psychologists. (I should hope that such research might be conducted unashamedly in collaboration with anthropologists and other social scientists.)

If we suppose that compatibility, or at least understanding, of attitudes and motives is important in the cross-cultural exchange, two related lines of development could be undertaken to test this supposition.

First, and at the risk of simplism, it would seem a good idea for the people of the United States to understand their own culture(s) and the degree to which--and the ways in which--their culture is represented in themselves. Such insight might be a good foundation on which to build in developing effectiveness in cross-cultural relations. Studies of "sensitivity training" as practiced at Bethel, Maine, by Gordon Lippitt and others (1962) suggest the merits of this approach.

The second step in a practical program would be to approximate an answer to my general question and then develop a catalog of specific answers for particular countries and cultures. Because the general question has not been well answered, the specific catalogs that have been developed tend to be speculative and disparate in approach. Both the U. S. Army and the U. S. Information Agency have supported studies designed to provide guidelines to persons concerned with communications within a number of foreign countries.

McClelland's studies of achievement motivation as a fairly widespread characteristic among Americans (1963), and his beginning of a cataloging of achievement motivation in other societies (1961), suggest the start of a collation of typical behavior patterns ("culture traits") whose intercultural interpretation might suggest ways of managing intercultural communication. As data accumulate from studies such as B. C. Rosen's (1962, 1964) of socialization and achievement motivation in Brazil, and that of L. E. Cortis (1962) on the attitudes of Bantu and European workers toward such things as security, status, and opportunities for advancement, our basis for intelligent matching of the relevant attitudes and values of different peoples to the purposes of effective cross-cultural communication will improve.

Coming back to military problems and military research, we find that a considerable number of studies of influential groups, communication media, attitudes, and appropriate thematic and symbolic material have been conducted for the Army by the Special Operations Research Office. These studies are accomplished on a country-by-country basis.

Although they are not analytic of the cross-cultural communication process in general, they are useful guidebooks to the person whose business involves communication with the peoples of other lands.

Current and planned research will shortly shed much more light on the role of the U. S. military man in this big business of cross-cultural influence. A study by Froelich (1965) on communication processes between U. S. military advisors and their Nationalist Chinese counterparts is a significant beginning. Likewise, in Korea, a study of U. S. military advisor relations with civilian communities should tell us something of the determinants of effective and ineffective cross-cultural communications. The slowly accumulating documentation of military-civic action programs worldwide also offers some hope of improving our understanding of how U. S. military advisors succeed and fail in their paramilitary work of nation-building in collaboration with their indigenous counterparts.

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CHAPTER 21

ALEXANDER R. ASKENASY

ROLE OF PSYCHOLOGICAL OPERATIONS WITHIN THE MILITARY MISSION

It is ironic that, whereas psychologists have shown only limited interest in "psychological operations," to non-psychologists the term has often evoked sinister associations with the mystique of psychology.

Psychological operations, narrowly defined in terms of leaflets and broadcasts, have often been considered a minor appendage to conventional military operations. Some writers have called in general terms for a larger role for psychological operations, but only rarely have we implemented such a role. My thesis is that in contemporary warfare, psychological operations must be integrated with other actions and that a social-psychological approach can be helpful in conceptually unifying all the diverse actions.

Clausewitz saw war as a means of changing the enemy's will or, we might say, as a form of psychological operations. As he defined it: "War is . . . an act of force to compel our adversary to do our will; . . . force . . . is thus the <u>means</u>; to impose our will upon the enemy is the <u>object</u>." (1953, p. 3). He stated the classical formulation of the military role: "War is a mere continuation of policy by other means," and " . . . politics is the womb in which war is developed, in which its outlines lie hidden in a rudimentary state, like the qualities of living creatures in their embryos." (p. 16).

Clausewitz was thus precociously aware of the psychological aspects of war. The point of war is not to destroy the enemy physically but rather to make him act in harmony with our will and to change his will to the extent that he no longer opposes our national interest. If we can influence the enemy's head, we will not have to strike his arm. In General Lemnitzer's words, ". . .The 'cold war' is fought on a variety of fronts: political, economic, sociologic, psychological, and military. Yet at root it is psychological." (1962, p. ii)

Burckhardt in his <u>History of the Renaissance in Italy</u> tells of the condottieri who moved their armies like chess figures without any fighting taking place, until one commander, perceiving he would lose the battle, conceded defeat. This example is not as anachronistic as it may appear. We need only recall the Cuban missile crisis. When we think of opponents in conflict war, we should visualize not robots

hacking at each other, but human beings with constantly changing perceptions, expectations, and alternatives.

BROADENING VIEWS OF PSYCHOLOGICAL OPERATIONS

Linebarger reports that "World War I saw psychological warfare transformed from an incidental to a major military instrument . . ." (1954, p. 62). In his opinion, this country's psychological warfare consists in "the supplementing of normal military operations by the use of mass communications (1954, p. 40). . . . Its place is a modest one and its methods are limited by our usages, morality, and law." (p. 43).

The outstanding example of psychological operations in World War I was Woodrow Wilson's Fourteen Points which appealed, with some success, directly to the people of Germany and Austria-Hungary. During World War I, the term "propaganda" was widely employed. Later on, the term became increasingly discredited--partly by Goebbels' use of it. The United States Army substituted the term "psychological warfare," and made extensive use of this "weapon" in World War II.

At the onset of both World War II and the Korean conflict, many psychological warfare lessons had to be relearned--a fact that points up the absence of a continuous military policy for psychological operations. In 1957, the Department of the Army replaced the term "psychological warfare" with "psychological operations," indicating a recognition that such operations do not require a formal state of war and that they are not directed solely against enemies.

Finletter argued that "Psychological warfare is a bad term because the word 'warfare' implies that deceit is justifiable if it serves our purpose, and that such a concept is neither consistent with our principles nor is it good business." (1954, p. 126)

In contemporary practice, psychological operations have tended to be conducted primarily on two levels: (1) as propaganda in the traditional sense, conducted by traditional means (leaflets, broadcasts, and so forth)[1], and (2) more recently in specific actions (medical programs, school construction, road-building) explicitly directed toward the change of attitudes and behavior of foreign populations in a direction considered desirable. On both levels, psychological operations have been viewed as subsidiary to conventional military activities.

[1] In Korea, for example, the United Nations psychological warfare agencies dropped 14 million leaflets in one week, in contrast to 3 million distributed by American troops during all of World War I.

We encounter too the not uncommon view that psychological warfare is somewhat disreputable or indecent. However that may be, the Communists are waging warfare psychologically today in places like Vietnam. As Dyer (1959, p. 210) puts it, "When one looks at Soviet political communication and compares it with our own, what stands out is the completeness with which the instrument has been integrated into all forms of Soviet activity... If we are to reply merely with counterpropaganda, or even propaganda, in the sense that the term carries today, we are at a disadvantage from the start."

A continuing dissatisfaction with the definitions used in this area has been reflected in the changing terms from "propaganda" to "psychological warfare" to "psychological operations." Other terms have been proposed. One source lists no less than 18 such expressions (Perusse, 1958, pp. 25-26). In England, the term "political warfare" came into use, meaning "combined operations of diplomacy and propaganda." (Schramm, 1955, p. 67). Lasswell (1951, p. 264) says, "Political warfare adds the important idea that all instruments of policy need to be properly correlated in the conduct of war."

In practice, journalists, public relations men, and advertising specialists have often been called on to conduct psychological operations. Working from trial and error, they have often done skillful, sometimes ingenious work (See Lerner, 1949), even though their experience has usually been in the domestic communications industry. One British World War II expert concluded that "many of the techniques employed by journalists and advertisers are not applicable to propaganda operations" (Crossmann, 1958, p. 39).

PSYCHOLOGICAL OPERATIONS IN CONTEMPORARY WARFARE

In contemporary warfare, the role of psychological operations has increased in importance. There are two reasons:

1. As Morgenthau (1961) has pointed out, aristocratic internationalism has in the last 200 years been replaced by nationalisms with competing ideological claims, and increasingly wider groups have become involved in government.

2. More recently, nuclear weapons have reduced the feasibility of full-scale wars to settle policy issues. It is becoming increasingly clear that psychological operations are less costly than combat. While formerly the psychological aspects were a small part of an essentially military struggle, now, especially in a cold war, military aspects have become a relatively minor part of an essentially psychological struggle.

The so-called little wars and the insurgencies in developing countries have been recognized as crises which cannot be fought by force of arms only but which pose major political, economic, and psychological problems (cf. Rostow, 1961). It has become essential to win the allegiance of the civilian population, preferably before an insurgency starts(Trinquier, 1963). Mao Tse-Tung has said that the masses must first be convinced and aroused before they can be organized. Guerrilla action can come only later (Rigg, 1961, p. 226). General Giap of the Viet Minh has similarly maintained that propaganda is more important than fighting (1962, pp. 78-79). (See also the accounts of Communist propaganda integration in Asia, Daughterty and Janowitz, 1958, pp. 828-857).

The revolution of rising expectations in developing nations cannot be contained by police action. Any long-range solution must take into account a people's national, economic, and social aspirations. The French found this to be true in Algeria. As Colonel Frequelin (1964) has pointed out, the French Army started out to control the terrain and only later became concerned with the aspirations of the population.

PSYCHOLOGICAL EFFECTS OF MILITARY OPERATIONS

General Wheeler (1963) has pointed out that the Army's mission is to conduct combat operations on land which are well understood by ourselves, by our friends, and by our enemies. He further stressed the need for credibility and visibility of Army powers.

It may be argued that the military commander very often is not aware of the psychological implications of his conventional military operations. Yet all military actions can have psychological effects on perception and behavior whether or not the commander intended such effects. Indeed, such unintentional aspects of military operations may have a greater influence on the will to resist than do calculated schemes. Military political, economic, and psychological actions may, then, be viewed as communications, as processes through which intentions are more or less conveyed. Psychological operations should be seen as a coordinated approach to influence the opponent's way of thinking and acting.

In my opinion, one shortcoming of psychological operations in developing countries is that communication is addressed primarily to the well-to-do upper or middle classes which represent the status quo, while far less attention is given to the majority of the population. As Osanka (1964) said, "the ruling powers (in underdeveloped countries) seldom view the peasants as an important or powerful political threat. Insurgents, and particularly Communist insurgents, take the opposite view." In the long run, it seems difficult to maintain the allegiance of a developing nation by relying only on the upper classes. Smith (1952) argues that, over time, the middle and upper classes have to

work within the limits of the value constellation of the villagers whom they "govern", or be ousted.

What we need, then, is a clearer picture of the persons with whom we are communicating, the persons who play important roles in modern war and insurgency. They include not only the statesmen and military officers but also the common soldiers and the peasants, the students, and the frustrated intellectuals to whom the Communists seek to appeal.

CHANGING PERCEPTIONS

Cantril (1941, 1958, 1963) developed a theory which brings together perceptual research and the individual's relations to society and social movements. He holds that we must deal not only with the "objective" world surrounding a person but also with his perceptual world--the world as _he_ sees it. People have lived for centuries with poverty and accepted it as unchangeable; then, suddenly, they find it intolerable and act to change it. We must concern ourselves with what has brought about this change in a people's aspirations.

A man's perceptions have developed in a given cultural and social setting. It is the task of the commander and the planner to restructure not only the "real" situation of an opponent but also the situation as the opponent perceives it. This is done not only by propaganda leaflets but also by a wide range of other means. The military commander through actions at his disposal can change not only the opponent's will to fight but also his perceptions of us and of our intentions. The commander should ask himself: What do the men opposing us expect us to do? What would they like to see us do?

All too often there is a tendency to project the standards and assumptions of our own nation into the minds of people of other nations. One example of this projection is concerned with so-called "legitimacy". A nation may communicate sympathy and support to another nation for its "legitimate aspirations for freedom, progress, and peace." In effect, such a nation sets itself up as a judge of right and wrong, forgetting the views of the people concerned, many of whom may oppose their established government and may even use illegitimate means because they feel their legitimate aspirations will not be fulfilled under the status quo. Too, the concept of treason is a relative one, as Boveri (1963) pointed out in her work, _Treason in the Twentieth Century_. A person may feel that being loyal to the regime, he in effect betrays his nation or social group.

Bauer (1964), in his recent article on influence processes and resistance to communication, found need for two levels of analysis, one to account for "the intentions of the regime" and the other to explain the "intentions of the citizen" (p. 324).

In developing countries, where rapid technological change occurs while traditional customs persist, there is need for perceptual restructuring, for a new "definition of the situation." Communism tries to provide a ready-made doctrine which seems to explain all the disturbing changes. Communism tries to offer a common language as an aid to effective communication, to provide categories of thought, and to spread belief in the ultimate triumph of Communism as a historical necessity--a new version of "God's will" (Selznik, 1960, pp. 39-40).

The military commander must be concerned with what he communicates to the enemy leader. What should the enemy know? What should he not know? What impression should he get? As the enemy leader will base his plans and operations in part on his perception of our strength and of his own, what can we do to change this perception in a way favorable to us?

PERCEIVING THE ENEMY

In war, there has been traditionally a clear dichotomy between friend and foe, between the "goodies"and "baddies." Gray (1959) distinguished four "images of the enemy": first, as a professional colleague--a comrade in arms; second, as subhuman; third, as devil and enemy of God and the good; fourth, as essentially decent but misguided. Osgood has repeatedly (for example, 1964) questioned the implicit assumptions we make about our own motivations and about those of the enemy.

In a world war, it is relatively easy to create in a few years simple, endlessly repeated stereotypes. When we are trying to win over enemy soldiers or even leaders, however, it will not help to tell them that they are criminals. In guerrilla warfare, the identification of the enemy becomes increasingly difficult, and the problem of communicating with him the more complex. Who is the enemy in an insurgency in a developing nation--the guerrilla fighter, his military leader, his political leader, a foreign power, hunger, or social crisis? Our military have shown a growing awareness of this complexity by their increasing emphasis on civic actions either combined with regular military operations or as preventive measures.

In the long run, if we want to win over people who are now in opposition to our national interests, neither conventional military nor narrow psychological operations will do the trick. To find a modus vivendi, we must identify "the common purposes, the common interests, the common values of the free world" (Taylor, 1952, p. 194). Smith (1952) suggested that the United States gradually redefine political freedom, economic security, and individual dignity in ways both we and non-industrial nations can agree on. Much of what was said about perceptions and expectations holds not only for foreigners but also for ourselves. Nor can one see communication as a one-way street for influence. Bauer (1964) advocated a "transactional" model of communication; there is "an exchange of values between two or more parties."

ALTERNATIVES OPEN TO THE ADVERSARY

What alternatives does the soldier or guerrilla perceive as open to him? What value priorities does he attach to these alternatives? Should he resist? What else can he do? These questions are closely related to his will to fight. Most guerrillas fight not for the sake of fighting but because they expect to reach certain goals which they feel cannot be reached by other means. Decision and game theories have not been too helpful in accounting for these processes. Values are subjective and choices are often made on emotional grounds. Nonetheless, it may be useful to think in terms of alternatives and of the probabilities and utility values attached to them.

Lerner in The Passing of Traditional Society (1958) concluded that mass media create the psychological capacity to imagine alternative ways of life and to perceive oneself in new situations and strange roles. Psychological operations in both the narrow and the broad sense can create and change alternatives. Consider some historical cases--oversimplified, of course. President Wilson's Fourteen Points were widely accepted by people of the Central Powers as an attractive alternative to continued fighting in World War I. In World War II, the Allied insistence on unconditional surrender is said to have stiffened German resistance. In the Philippines, Magsaysay offered amnesty and free land to Huk guerrillas who surrendered, giving them a most desirable alternative to fighting. In Malaya, the British made surrender more appealing by using such terms for it as "leaving the jungle" or "self-renewal."

The Communists, of course, are old hands at the formulation of drastic alternatives. Marx and Engels assured the proletarians that they had nothing to lose but their chains. A typical Communist tactic is to eliminate all alternatives which might have wide popular support by insisting, for example, that democratic reform parties are only the ancien regime in a new guise and at the same time outbidding such parties with irresponsible promises. It is not poverty itself which leads to rebellion, but the belief that now there is an alternative to poverty. Once the popular feeling grows that there is a need and a possibility for change, one cannot for long counteract it with appeals to the status quo. What does this leave for us to do? We might seek to tell the audiences that while we are legitimately assisting an established government (which may be identified with past unpopular policies), our activities point toward a more desirable future and present a positive alternative to Communist promises.

In the broad sense, psychological operations should aim at changing the opponent's perceptions so that resistance no longer appears to serve his interests. From his point of view, he acts in his own interest, which others are resisting. Psychological operations, rather than destroying the enemy, can aim at converting him to see things differently. They can persuade him that it is in his long-range interest to work with

us toward a future that satisfies his hopes and expectations. Thus, a common denominator must be found which takes into account the interests of both sides. If there is a one-sided preponderance of military or other power, the formula may neglect the interests of the other side. Such an equilibrium is likely to be short-lived. As soon as the weaker side gains strength--or perceives itself as having gained strength--it is likely to challenge the status quo. Therefore, long-range stability tends to require the acknowledgement of national interests as perceived by both nations involved.

COORDINATION OF MILITARY AND CIVIC ACTIVITIES

Just as the U. S. Army has shown its flexibility in developing new units, training methods, and doctrine for unconventional warfare, so it can adapt to the demands for extended psychological operations in contemporary warfare and insurgencies. The military commander in the field should be able to coordinate psychological and standard military operations, to plan and recommend military activities not only in terms of immediate military results, but also for psychological effect, both immediate and long-range. Magsaysay in the Philippines gave an impressive example of efficiently integrated military and psychological operations.

Although coordination of operations by the Army and other government agencies for psychological effectiveness has long been practiced, some specialists hold that such coordination has at times been incompletely achieved. Crossman for one (1952) has warned that ". . . .psychological warfare may do more harm than good unless it is strictly coordinated with diplomatic and military activity."

For efficient psychological operations, the military--and, for that matter, the political--decision makers must see their actions as a united whole. Even though different activities have been assigned to different government agencies, it would be dangerous to assume that the psychological processes involved fall into corresponding separate slots rather than being unitary and continuous. The Communists have been quite aware of this danger and have acted accordingly. We would neglect this unity at our own risk.

In order to conduct and maintain effective military and psychological operations, personnel must be sensitized to the psychological implications of potential actions. Some such sensitizing training should be given not only to explicitly labeled psychological operations officers but also to commanders who make important decisions and to troops who are in contact with foreign populations.

SOME SUGGESTIONS FOR FUTURE RESEARCH

Various lines of research can help the military to maximize the psychological effectiveness of their actions. Vallance (1951), Riley and Cottrell (1957), and Daugherty (1958) have discussed needs for research and reviewed relevant studies on psychological operations. Within the time limitations of the present paper, only the briefest suggestions for research can be made:

Perception. Perceptual research on the relations between the individual and his social and material surroundings is particularly relevant. Existing literature on perceptual frameworks and their change should be reviewed and expanded. Much work needs to be done on the measurement and change of values. We are interested in the economic, social, and political givens and the alternatives to them as perceived by certain groups. A topic of specific interest is the immediate and long-range effect of surprise actions on the perceptual framework.

Communication. How can one communicate one's intentions so as to minimize the chance of being misunderstood, particularly by the opponent? What ideas, appeals, and issues are the most potent seed of multiplier effects? Systematic research also needs to be done on non-verbal communication.

Interplay of Communications. What is the interplay of different forms of action? What psychological actions are especially influential before, during, and after military actions? We are interested not merely in how we can improve communication but also in how we can change people by communication and other means.

Audience. We need a clearer picture of the persons to whom we must address ourselves in modern war and insurgency. Our audience includes the common soldiers and the peasants, the students, and the frustrated intellectuals to whom the Communists seek to appeal, as well as the statesmen and military officers. The military commander needs generalized models of the groups with whom he is to communicate, particularly in an insurgency or pre-insurgency situation. It might be helpful to specify methodological approaches and guidelines for obtaining economic and political as well as psychological data. Some work along these lines is now going on with emphasis on ideals which appeal in different cultural settings. Cantril (1963) has been studying the aspirations and fears of sizable samples in a number of countries, and the U. S. Information Agency has done extensive research on the image of the United States abroad.

Effects. The evaluation of the effectiveness of psychological operations is beset by many difficulties. Nevertheless, concern with effects is central to psychological operations. It will be useful

to outline possible effects and spread of influence, and to develop further means of measurement and criteria of reliability and validity. An interesting topic for investigation would be the unintended psychological side effects of "straight" military actions. As communication is a two-way process, there is need to develop and analyze feedback of psychological operations.

General Problems. In conclusion, there is need for further articulation of the objectives and processes of psychological operations. A meaningful model of psychological operations should take into account 1) the given national objective; 2) the psychological situation as well as the economic and political situation of the population involved; and 3) the effects of psychological operations and of other actions on the perceptions and behavior of the population addressed. Key issues and working concepts should be developed which both meet the operational requirements of the military and satisfy the standards of social scientists. In this sense, psychological operations as a field may bring military and psychological thinking more closely together.

Psychological operations, rather than destroying the enemy, can aim at converting him to see things differently. They can persuade him that it is in his long-range interest to work with us toward a future that satisfies his hopes and expectations.

This paper has tried to avoid viewing psychological operations as a minor adjunct of traditional military activities and as applied publicity or advertising. It seeks to offer a wider, psychologically meaningful approach, designed to assist the military commander in accomplishing his total mission.

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CHAPTER 22

LORAND SZALAY

RESEARCH REQUIREMENTS OF INTERCULTURAL COMMUNICATION

The Army's intensive interest in effective communication with foreign nations is a result of its increasing range of activities and involvements. Worldwide political and military commitments dictate the presence of large numbers of U. S. military personnel in alien cultural environments. These persons must execute delicate tasks of advising, teaching, and leading both individuals and groups. The success of their efforts depends on the effectiveness of their contacts. In turn, effective contact is contingent upon effective communication. In a foreign environment, the advantages that can accrue to our military personnel from their outstanding skills and weaponry often depend on the amount of genuine understanding established with indigenous colleagues and audiences.

Military authorities charged with counter-insurgency operations and anti-guerrilla warfare realize that achievement of their mission is not so much a matter of weapons superiority as of establishing efficient communication with broad segments of the population.

Elvis J. Stahr, former Secretary of the Army, spelled out clearly this up-to-date orientation: "To prepare properly...military representatives of the United States abroad, we need far more than military specialties. We need to know intimately the peoples and their habits of mind, the languages, the customs, and how best to approach each individual problem. The research and compilation of all the information we need are beyond the capabilities of the Army."

In the military context, problems of communication are encountered in psychological operations, in the conduct of military advisory missions, in counter-insurgency, and in training assignments. The many types of operation and the unusual labels should not be allowed to obscure the basic problem in common: intercultural communication.

The present chapter deals with research requirements, data, and methods necessary to establish efficient intercultural communication. What do we need to know? How do we find it out? What type of research must we pursue in order to reach foreign, culturally alien audiences effectively?

NEED TO SPELL OUT THE MILITARY REQUIREMENT

In an ideal situation, the operational requirements should be spelled out with sufficient specificity to allow a clear decision as to whether a particular research approach is suitable to the task. But while the acute need for operational improvement in intercultural communications overseas is recognized by the military, there is little specificity in the description of information needed by the Army. We usually find very general references to the need for cultural information. There is, of course, even less specificity as to the type of research asked for.

One may argue that specification of this type is a professional matter and should be the task of psychology and the social sciences. But we find that the behavioral and social sciences do not spell out specific information needs nor do they offer research approaches and instruments perfected for the operational needs.

This is not to say that the social sciences have completely neglected a field which so obviously lies within their intellectual domain. Rather, their contribution has heretofore been based on methods developed originally for other purposes. They have tended to apply methods and instruments utilized by or developed in cooperation with scientists in such fields as communications research or cross-cultural research, but not methods adjusted to the specific needs of intercultural communication.

SORO'S USE OF AREA SPECIALISTS

An example of an intercultural communication task is PSYGUIDE. This is a research effort of the Special Operations Research Office (SORO) to compile symbolic and cultural information necessary for the conduct of overseas propaganda and other types of successful intercultural communication. Because better techniques were not available, SORO developed a data collection method of synthesizing judgments on appropriate procedures and interests by a number of area specialists, persons not indigenous to the local society but who had had direct and recent experiences in the particular society and culture. This technique maximizes the operational pertinence of material but without as much detail as could be derived from indigenous peoples. While U. S. consultants can be trusted to give information honestly, they cannot know--no matter how many years they may have spent in the society under study--the myriad patterns of thought which in specific cases or in the aggregate can result in action or attitude so different from that which would be expected in one's own culture.

The exploration of thought patterns, culturally conditioned referential meanings, and value orientation falls generally within the competence of psychology; yet, despite the great variety of techniques available, no technique has proved to be both relevant and adequate in efforts to extend data collection directly to foreign samples.

It is difficult to obtain valid results from direct questioning of the indigenous population. Attitude measurement techniques--if adjusted culturally--reveal likes and dislikes, but it is not always clear what these imply, nor even to what they actually refer. No adequate projective techniques have been developed to handle the problem, nor do we have other tests which could be used in this context. We do not have experimental methods to solve even such simple and basic problems as whether a particular term is utilizable or not, and what type of reaction it elicits from an alien audience.

SUGGESTED EXPLORATORY STEPS

The unspecific character of the actual research support and the need for specific operational research requirements suggest the adoption of the following steps in our present search for appropriate research alternatives:

1. A review of sources supporting the recognition of intercultural communication as a new field characterized by specific research requirements.

2. An analysis of intercultural communication with special regard to its relationship to the problems of neighboring regions in order to isolate distinctive characteristics calling for specific research capabilities.

3. The use of these problem characteristics for determining the type of research needed.

4. Finally, a brief reference to cultural data obtained in other research efforts based on similar considerations.

This approach will hardly allow us to evaluate various research methods--individual attitude measurement techniques, for example. However, it may supply us with criteria for such evaluation as well as with orientation for selection of methods useful in furthering intercultural communication.

DISTINCTIVE FEATURES OF INTERCULTURAL COMMUNICATION

As to the new problems contingent upon intercultural communication, Riley and Cottrell emphasize that this field has specific requirements in respect to the level of approach as well as content. Daniel Katz, discussing psychological barriers to communication (1947), also makes a strong point about fundamentally new requirements. "In brief, the psychological barriers to communication are of such strength and have

such a deep foundation in human nature that the whole problem of social communication between individuals and groups needs to be re-examined in a new light. No single formula will solve the problems arising from the complex causes and widely ramifying aspects of limitations of the symbolic mechanisms and other psychological processes." Margaret Mead, in her book, The Communication of Ideas (1945), calls attention to a particular category of problems which emerge "when cultural boundaries have to be transcended." Hartley and Hartley (1962) analyzed such barriers psychologically. They emphasize that communication exists only in units of personal experience and that effective communication between two people or two groups of people is possible only to the extent of their common experience. They conclude: "In considering the effects on communication of profound differences in levels of experience, we must take into account the way in which the whole pattern of culture develops certain values and concepts which have validity within the framework of that particular culture. The operation of this cultural patterning is sometimes so pervasive and basic to the thinking of people who have not experienced any other that they cannot understand a communiqué if it is postulated on a different set of norms."

Next, we may explore distinctive features of intercultural communication as the natural source of new research requirements. This is in the sense of Vallance's suggestion that in order to improve cross-cultural communication we should analyze the communication problem in a cross-cultural context. We can best understand intercultural communication by exploring the differences in situational variables and the functional principles which distinguish it from common or intracultural communication. A brief summary of these differences is presented in Table 1.

While transcending cultural boundaries does not necessarily involve technical difficulties, the comparison outlined in Table 1 indicates that, from a psychological angle, intercultural communication creates a number of new problems.

Differences in language and in cultural experiences are obvious situational characteristics peculiar to intercultural communication efforts. Easy recognition of these differences, however, does not imply a similar ease in finding appropriate measures to overcome them. An important difference in the communication process may be observed by comparing the basically automatic routine character of common (intracultural) communication with the elaborate planning requirements of intercultural communication. The native speaker uses his own frame of reference in formulating his message. What he says and how he says it is a matter of automatic routine.

Table 1

DIFFERENCES IN COMMUNICATION SITUATION

	INTRACULTURAL COMMUNICATION	INTERCULTURAL COMMUNICATION
Situational characteristics	Common language, experience, values, frame of reference.	Differences in language, experience, values, frame of reference.
Principle of functioning	Speaking within his own culture, the communicator uses in an unconscious, automatic way his own frame of reference and puts into the message what "he has in his mind." Thanks to prevailing community of experience and language, the message is understood by the recipient.	The communicator cannot simply and automatically utilize his own frame of reference in approaching a culturally foreign audience. He must in advance: (1) analyze the audience to determine differences, and (2) systematically design communication to take advantage of existing communalities.

In intercultural communication, the foreign audience should be the basis of orientation, and, to be effective, the communication must be appropriately adjusted. This adjustment creates a number of delicate methodological problems. First of all, it presupposes a systematic exploration of differences. Further, as common factors decrease and the disparities to be overcome increase, systematic planning must be substituted for the original automatic process. This substitution necessitates an elaborate design requiring both information about the audience to be reached and a detailed strategy for utilizing the information.

Table 2 presents contrasting research requirements for the two kinds of communication. A number of items worthy of attention are shown, but for the sake of brevity I shall concentrate on a single characteristic difference in methodological requirements. Communication research in the conventional sense is primarily concerned with the effects of communication as reflected in attitude changes. This research strategy relies heavily on the measurement of attitudes and behavior. The research requirements of intercultural communication include much more than the

Table 2

DIFFERENCES IN RESEARCH OBJECTIVES AND METHODS

	INTRACULTURAL COMMUNICATION	INTERCULTURAL COMMUNICATION
Research objectives		Analysis of cultural-ecological factors with special regard to their communication-relevant differences. Assessment of cultural perception, meaning, values, and frame of reference. Designing communication appropriate in form to overcome the cultural differences. Methodological studies: How to overcome differences in experiences, values, etc. How to adapt communication content to different frames of reference, language medium, etc.
	Measurement of the influence of communication variables: Sequence of presentation, media effects (film, print), form of presentation acoustic, visual, etc.).	Measurement of the influence of communication variables: Local cultural relevance of sequence of presentation, media, and form.
	Measurement of effects: Measurement of attitude and opinion changes. Measurement of changes in behavior.	Measurement of effects: Measurement of attitude and opinion changes in different cultures. Measurement of changes in behavior.
Research instruments	Attitude scales, questionnaires, and other instruments of attitude and opinion measurement.	Adjustment of existing attitude and opinion techniques to the cross-cultural requirements of administration. Development of new techniques for measuring cultural perception, verbal relatedness, denotative meaning; analysis of cultural value hierarchy; mapping of the organization of the culturally characteristic frame of reference.

evaluation of communication effectiveness. The collection of cultural information about communication-relevant characteristics of the audience becomes indispensable. The information must be fundamental; it is not enough to ask if an audience likes or dislikes a particular issue. Prior to exploring likings or measuring attitudes, it is fundamental to determine what representatives of a given culture understand by the particular issue. When designing messages for home audiences on a particular question, the communicator is generally familiar with what people have "in their minds" on the subject. The situation is different with foreign and culturally alien audiences. The literature is rich in data indicating how differently people of various cultures perceive, relate, interpret, understand, and evaluate a particular issue. Take "socialism," the experiences of foreign audiences are not the same as those of people of the United States; they connect "socialism" with different ideas (industrialization, rising standard of living, progress, planned accelerated economic development); their dissimilar values and value hierarchies make it likely that the value components (equality, nationalism, prestige) of their perception are different.

No persuasive intercultural communication is possible unless the communicator is knowledgeable about the nature and extent of differences between him and his audience. Accordingly, methods are required in intercultural communication research which put main emphasis on exploration of relevant communication variables--culturally conditioned perception, denotative-referential meaning content, cognitive organization, value orientation, and so on.

Finally, intercultural communication is distinguished from the vast and amorphous category of "cross-cultural research." To avoid confusing the problems of intercultural communication with those of cross-cultural research, I reserve the label "cross-cultural research" for a large and undefined category of research efforts, whose objective is to obtain comparable data from the largest possible number of societies in order to explore the generality of individual or group characteristics. Research in support of intercultural communication, on the other hand, has clear objectives and a definitely limited range. It must concentrate on a specific foreign culture at a particular time and it must explore definite categories of verbal-cognitive characteristics and cultural value orientation.

Table 3 presents the research objectives peculiar to intercultural communication in juxtaposition to those of "cross-cultural" research. The methodological conclusions are basically analogous to those appearing in the previous comparisons in Table 2.

Table 3

DIFFERENCES IN RESEARCH OBJECTIVES AND METHODS FOR CROSS-CULTURAL RESEARCH AND INTERCULTURAL COMMUNICATIONS

	CROSS-CULTURAL RESEARCH	INTERCULTURAL COMMUNICATION
Scope:	Broad multicultural comparisons representing a basic trend toward including as many cultures as possible in the experimental comparisons.	Narrow bicultural comparisons with explorations limited to a particular culture of communication interest.
Subject matter	Any subject of psychological, anthropological, social, or scientific relevance.	To explore cultural differences in perception, meaning, value orientation, and culturally shaped frames of reference instrumental in determining the effectiveness of intercultural communication.
Research instruments	All tests, research techniques, and experimental methods which are applicable or adjustable to the requirements of cross-cultural administration.	A limited number of techniques suitable to the analytical research objectives--analysis of connotative and denotative meaning, analysis of cognitive organization, analysis of cultural value hierarchies, etc.

Briefly, intercultural communication should not be handled as a subcategory of intracultural communication of communication research in the conventional sense, or of cross-cultural research. It should be recognized as a new and independent research area characterized by special needs, information and research capabilities.

RESEARCH METHODS

These requirements, inherent in the nature of the intercultural communication tasks, imply basic shifts in research orientation.

The present hegemony of attitude measurements has to be replaced by a more sophisticated and elaborate analysis of the frame of reference and cognitive organization peculiar to a specific culture. As a practical alternative, the componential analysis designed by Goodenough (1956) and Lounsbury (1956) may be mentioned; various available alternatives of content analysis are described by Lasswell (1949), Berelson (1952), Poole, and others.

The study of indigenous cognitive organization requires analysis of the native verbal relatedness patterns and of the denotative meaning content. In a practical approach, associative measures similar to Cofer's "mutual frequency," Deese's "overlap coefficient "(1962), and Garskof's "relatedness coefficient," (1963) seem to be adoptable, as do also similarity ratings based on triadic comparisons--see Rowan (1954), Forster (1964), and others.

As opposed to the basically one-dimensional (positive-negative) evaluation, practical methods of multidimensional value analysis useful in mapping culturally-specific value hierarchies are needed. Triandis' (1959) proposal concerning the selective increase of concept relevant scales in the semantic differential represents a move in this direction.

In evaluating these methods and developing others, the main criterion should be their usefulness in the cultural adjustment of communication and their instrumentality in increasing intercultural communication effectiveness.

SORO EXPERIMENTS

In the context of these requirements, it seems appropriate to refer to certain experimental results obtained by SORO. These experiments, not yet completed, were designed for the practical information needs of various intercultural communication tasks. The results obtained using verbal association tasks indicate methodological potentialities.

Three cultural groups took a word association test in their native language. For each stimulus, the subjects were asked to give as many free associations as they could within one minute. The associative responses obtained from various cultural groups (U. S., Korean, Colombian students) were found to be highly culture-specific and supplied rich material for inferences. Associative affinity indices were calculated for combinations of the stimulus words in each cultural group. These indices are based on the proportion of responses common to two stimulus words and were obtained in much the same way as were the associative measures developed by Cofer and others on English associations. High

associative affinity values indicate a high level of verbal-cognitive interrelatedness.

Intercultural associative affinity data gives illuminating cultural information if compared interculturally, permitting us to trace the culturally characteristic verbal-cognitive organization. Such data also afford an opportunity for quantitative evaluation of cultural differences. The matrix of the indices presented in Table 4 shows a set of such interrelatedness patterns for three culturally different groups. Take the first instances. HUNGRY and POOR show significantly lower affinity for the U. S. group than for the foreign groups representing countries with a definitely greater problem of poverty. Similar differences are reflected in the interrelatedness patterns between HUNGRY and the other words dealing with economic-financial status (MONEY, BEGGAR).

Attempts were also made to utilize the associative responses obtained from various cultural groups by content analysis. Tables 5 and 6 show the distribution of responses obtained from the three different student groups to the stimuli FOOD and CAPITALISM. After reviewing the response proportions to FOOD in terms of the main content categories, additional attention may be paid to the breakdown of a single category--food varieties or specific foods, for example. As the single food items are marked by scores, we get here a food list distinguished by clear priorities. According to cultural experts, the food lists obtained from the various groups truly reflect the composition of the indigenous diet. There is also a high degree of consistency in such response patterns obtained by different stimulus words (FOOD, HUNGER, TO EAT). The high degree of cultural-specificity and the consistency of such patterns suggest that associative response material obtained from cultural groups and submitted to appropriate analysis supplies us with information about the culturally-specific denotative meaning content as well as its main cultural value components.

While there is nothing new in finding out that RICE represents the most important food for Koreans, the high level of correspondence found between associative data and cultural reality in the context of such concrete and verifiable items as FOOD makes it possible to place credence in the results obtained in connection with such abstract and highly evasive issues as SOCIALISM and CAPITALISM.

Table 4

INDICES OF INTRACULTURAL ASSOCIATIVE AFFINITY--U. S., KOREAN, AND COLOMBIAN STUDENTS

WORD STIMULI		Intracultural Indices													
		POOR		MONEY		BEGGAR		TO DESIRE		TO EAT		RICE		FOOD	
HUNGRY	US	205	210	88	80	165	165	114	119	427	412	135	146	495	346
	K	363	362	126	111	342	308	89	131	337	400	305	286	262	258
	C	418	363	195	148	370	390	158	162	304	296	229	257	342	267
FOOD	US	80	82	54	72	29	49	60	77	581	529	124	176		
	K	109	113	78	73	114	117	35	50	494	506	313	280		
	C	125	131	128	119	93	97	56	63	534	573	303	380		
RICE	US	80	80	59	53	62	57	45	44	149	127				
	K	125	181	76	88	64	71	36	60	387	397				
	C	82	64	83	62	65	55	37	33	340	270				
TO EAT	US	80	91	52	52	71	73	86	99						
	K	138	140	85	83	110	118	46	65						
	C	136	152	119	128	121	140	117	141						
DESIRE	US	109	110	143	121	123	119								
	K	150	106	200	128	113	84								
	C	109	101	155	127	83	77								
BEGGAR	US	385	315	141	91										
	K	425	374	166	124										
	C	550	418	153	135										
MONEY	US	144	194												
	K	190	207												
	C	199	278												

NOTE:

There are two columns of indices in each cell. The left-hand index represents the intracultural affinity of the word stimuli listed in the left-hand column to the word stimuli listed in the upper row (HUNGRY to POOR).

The right-hand index represents the intracultural affinity of the upper row stimuli to the left-column stimuli (POOR to HUNGRY). Comparing the intracultural indices between the three cultural groups, a difference of 55 is significant at the 0.05 level and a difference of 83 is significant at the 0.01 level.

Associative affinity of concept A to concept B is defined by the following proportion:

$$\frac{\text{A associates in common with B and with B associates}}{\text{Total of A associates}}$$

This proportion is used as an index to quantify the relationship of selected verbal stimuli in respect to a particular cultural group.

Table 5

RESPONSES TO "FOOD" BY CONTENT CATEGORIES FOR THREE NATIONAL GROUPS

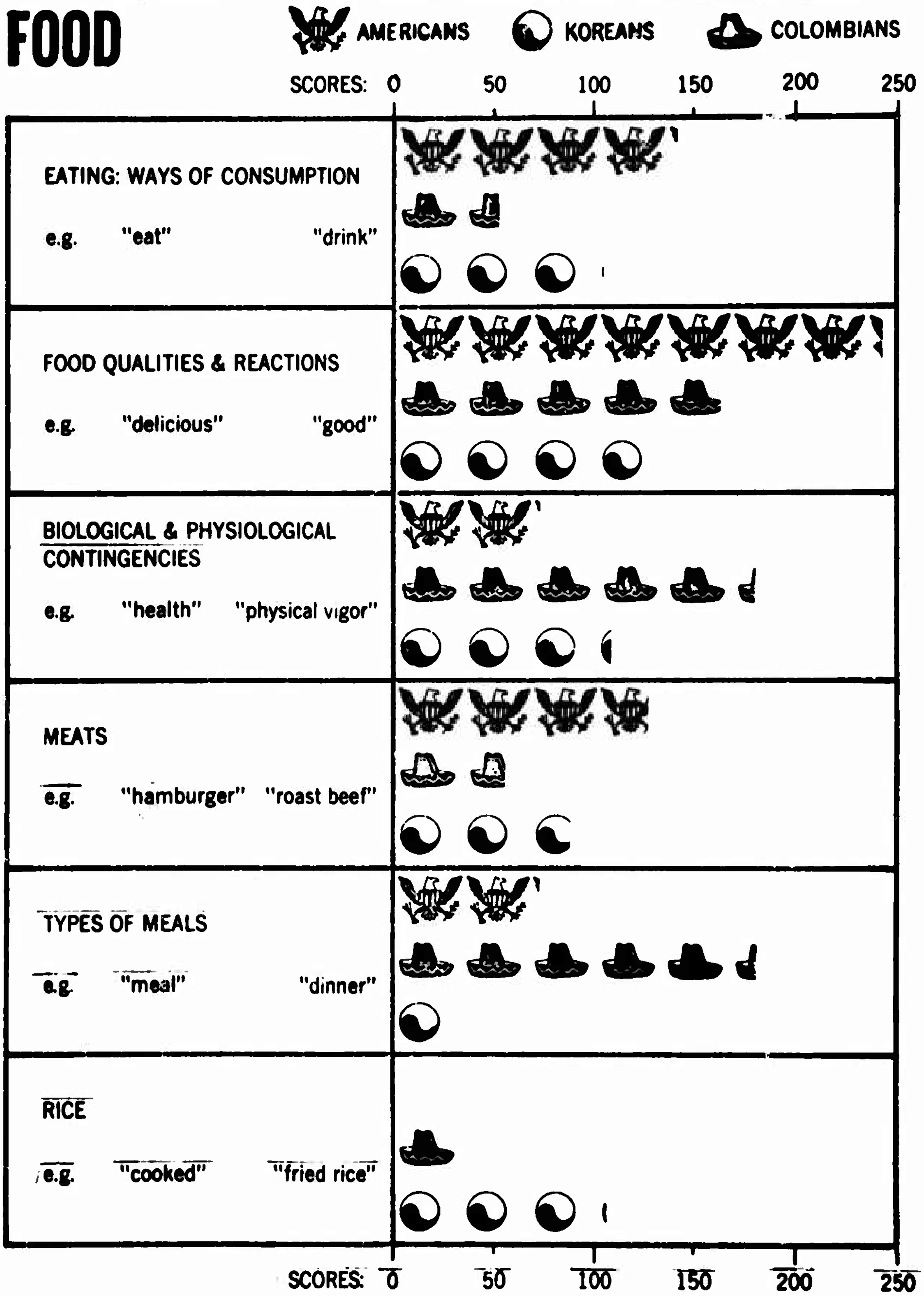
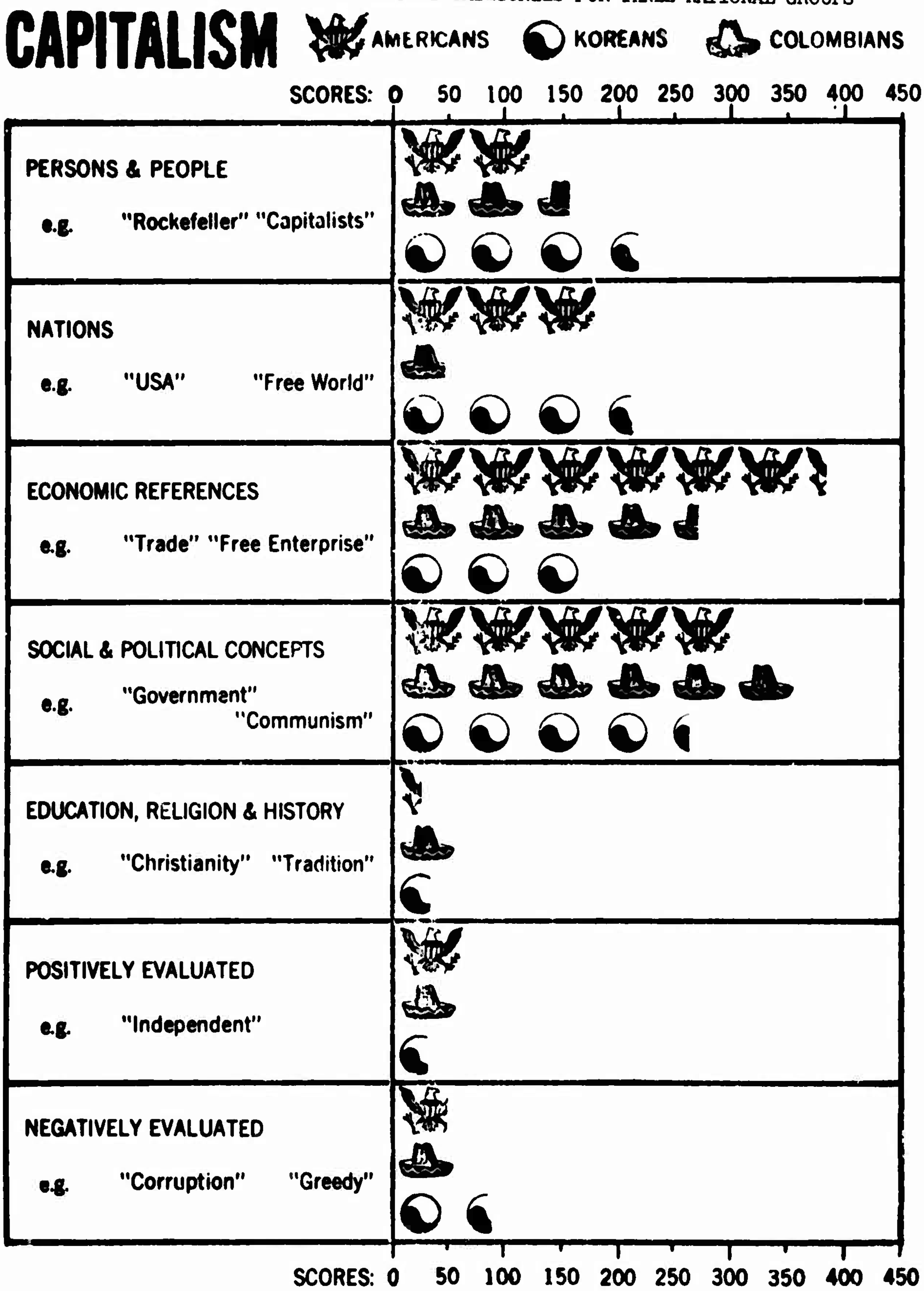


Table 6

RESPONSES TO "CAPITALISM" BY CONTENT CATEGORIES FOR THREE NATIONAL GROUPS



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PART X

UTILIZING POSTURE STRATEGIES AND WEAPONS SYSTEMS AS INSTRUMENTS OF INFLUENCE

INTRODUCTION TO PART X

The two papers reproduced here as Chapters 23 and 24 constitute a critical survey of the methods and techniques which are being developed and applied in support of policies adopted by a nation with the objective of influencing and deterring actions of other nations or peoples. The session was organized and chaired by Dr. Thomas W. Milburn, U. S. Naval Ordnance Station, China Lake, California.

In Chapter 23, Dr. Robert Davis, Systems Development Corporation, Washington, D. C., assesses the validity of the contributions of social scientists--psychologists in particular--to national efforts to influence the behavior of other nations. Environmental or operational simulation which "sets the model in motion", Dr. Davis concedes, preserves the complexity of the environment and has greater face validity than the more abstract static models. But whether results of these "games" can be extrapolated to the real world remains arguable, since they lack the emotional overtones of the real-life situation. Dr. Davis assumes that as a minimum they produce useful insights.

In citing instances in which psychologists have drawn on findings from research conducted on animal and human subjects, Dr. Davis again considers as open to question the usefulness of extrapolation to the complex international situation in view of the degree of abstraction characteristic of the controlled experiment. A special case of generalization from traditional research is the game theoretic approach in which empirical data are collected about how men behave in negotiating and bargaining situations. The mixed-motive or non-zero-sum game introduces uncertainty about the player, his value system, and his strategy, allowing both competition and cooperation. While not advocating substitution of research scientists' models for the personal model on which policy makers base their decisions, Dr. Davis sees models and games as a means of educating the decision maker to the complexity of world problems, of alerting him to aspects of reality of which he may not be aware, of helping him make his own model of reality more complete.

Dr. Milburn, in Chapter 24, summarizes as follows his wide-ranging discussion of the variables in international deterrence strategy: ". . . the major contributions to concepts or variables for thinking about strategic deterrence have come from social scientists other than psychologists. These excellent contributions have neglected consideration of some important and relevant aspects of deterrence, such as the effects on perception and meaning of situational variables--stress level, communication structure and feedback, the effects of past experience on adaptive behavior, and the importance for attempts at deterrence or positive influence of defining goals and criteria for meeting the goals. Psychologists can perhaps be encouraged to broaden their data bases in order eventually to provide theorists and policy makers with improved models. If one concludes that more valid insights are obtained by those closest to the data,

then one major challenge facing psychology today is that of developing and using theoretically-based techniques for the study of the complex, quite real and very practical problems and issues facing mankind."

CHAPTER 23

ROBERT H. DAVIS

INTERNATIONAL INFLUENCE PROCESS: HOW RELEVANT IS THE CONTRIBUTION OF PSYCHOLOGISTS?

Before the advent of nuclear weapons, it was possible to base national strategy on the defensive steps that might be taken after a war broke out. Today, the emphasis has shifted from defense, which is now technically infeasible in the case of strategic nuclear weapons, to deterrence--to efforts to influence the decision to attack. This shift in emphasis has created an apparent opportunity for the psychologist to bring to bear on questions of national strategy data and insights gleaned from literally thousands of studies. My purpose here is to take a look at the ways in which social scientists -- psychologists in particular -- have tried to apply their skills and knowledge to the problem of influencing the behavior of other nations, and to try to assess the usefulness and validity of their efforts.

Although I opened my discussion by citing the deterrence problem as one heavily weighted with psychological components, I do not imply that deterrence is the only aspect of the international influence process toward which psychologists have directed or should direct their energies. Deterrence is essentially a negative concept, a strategy which threatens punishment in an effort to discourage certain forms of behavior. Based on threats, deterrence can lead to increased tension. Clearly, there are alternatives to deterrence. One is encouragement through reinforcement. Charles Osgood (1962) has repeatedly advocated steps which would reinforce desired behavior of other nations and reduce international tension.

Rather than attempt to evaluate the contributions of individual psychologists, and possibly lapse into ad hominem arguments, I prefer to ask: How have psychologists attacked this problem? What methods of analysis or research have they employed? To what extent have these methods provided useful and valid insights about the international influence process? And finally, what dangers characterize particular techniques?

At least four approaches can be identified: (1) psychologists have devised models of the international influence process; (2) they have designed simulations or games and conducted research using these simulations; (3) they have drawn on the vast body of research conducted on humans and lower animals to support arguments, models, and suppositions about national and international decision makers; and (4) in the interest of completeness, there is an approach widely used today, which has not been the special forte of psychologists but which still deserves discussion, namely, the game theoretic approach.

MODELS OF THE INFLUENCE PROCESS

It is a commonplace observation that the world we live in is extremely complex. We seek to unravel the simplest thread only to find that it binds together an enormously complex array of interdependent events. One of the ways commonly used to deal with this problem of complexity is the construction of models. Models are simplified representations of some subject of inquiry. They help scientists and philosophers alike to visualize and determine how changes in one aspect of the model would influence other aspects or how such changes would influence the whole. All models presume some relationship to the more complex reality they are created to represent; and since they are less complex and are directly accessible to us, they can be manipulated more easily than the real world.

Men have been using models to organize their understanding of the world for many centuries. Many of the models used by social scientists to help organize and stimulate thought have been derived from physical and mechanical systems. Descartes, for example, is identified with the rise of the mechanistic view of man--a view of man which he developed using primitive automatons as a model. Clark Hull's (1943) assumption that the brain acts as an automatic switchboard falls in the same mechanistic tradition.

Living organisms provide the basic analog for a second class of models. Organismic models stress the interrelatedness and integrity of a system, as well as notions of growth and evolution--a point of view developed in its most sophisticated form by the philosopher A. N. Whitehead (1950) and also familiar to psychologists for its relevance to Gestalt theory.

A notion implied by the classic organismic model is purpose, which many social scientists still reject as unscientific. The modern discipline of cybernetics (Wiener, 1954) has done much to define purpose in essentially mechanistic terms. These terms are now used quite widely to explain individual, social, and political behavior (Deutsch, 1963). The computer--and the development of computer programs--has also stimulated new ideas regarding purposive behavior (Miller, Galanter, and Pribram, 1960).

There are other kinds of models of interest to social scientists, including, of course, mathematical models. If we ignore for the moment models inspired by game theory (discussed under a separate heading), most of the models developed for studying the international influence process have been verbal. Yet the complexity of the international influence process requires the use of multiple models as well as verbal material for their elaboration. It would be possible to represent, for example, some of the features of Osgood's model of the international influence process by a flow diagram (Figure 1). Such a diagram is called an analog model (Churchman, Ackoff, & Arnoff, 1957). But this flow diagram does not begin to represent the features of the process which Osgood presumably believes are crucial to an adequate description of the situation. Osgood has drawn

extensively on experimental research in the area of perception to illustrate phenomena which are assumed to influence decision makers, and one might expand on the model shown in Figure 1 by constructing additional models to represent human psychological considerations.

David Singer (1962), a political scientist, has chosen a probability-utility model to illustrate some perceptual problems of deterrence. This model has two axes: a utility-disutility dimension which has to do with a decision maker's assessment of the positive or negative value of any given course of action; and a subjective probability dimension representing the decision maker's estimate of the odds. Values attached to the dimensions of his model vary with the particular situation in which the decision maker finds himself. Although Singer provides no concrete guides for assigning values to these dimensions, he assumes (pp. 25-26) that choice is a function of probability multiplied by success or failure. To illustrate, the model shown in Figure 2 is estimated outcome for the deterree and represents the ideal case from the point of view of the deterrer. Probability of success is low and the gain slight; probability of failure is high and the consequences relatively great.

Singer's model, like the model used to illustrate Osgood's approach, is completely inadequate to encompass the complexity of the problem. Singer himself relies primarily on verbal material rather than the analog model of Figure 2, and Osgood has not, to my knowledge, ever attempted to create an analog model of the strategy he has proposed. The requirement for multiple models is nicely illustrated by citing a third model, proposed by Karl W. Deutsch, to illustrate the flow of foreign policy information within a single government (Figure 3). There is no end to the models which might be constructed by a shrewd observer of a process as complex as this. On the surface, this observation may seem inconsequential, but is is a serious matter. In the absence of an agreement about models, all the facts which might be relevant to the process seem equally important. Data collection and even experimentation are consequently far more random than they would otherwise be. Thomas Kuhn (1962) has recently argued most effectively that the near universal acceptance of a paradigm providing research consensus is an essential step on the route to normal science. Social science, in general, has been plagued by lack of consensus regarding fundamental paradigms--certainly no such consensus exists in the present case. Yet, the construction of paradigms and agreement regarding them is essential if we are to convert our philosophy into science. Thus, the undertaking is to be commended. The danger lies in premature assumptions about the validity of our models and the courses of action we recommend on the basis of them. Let me illustrate by a contrasting example from the physical sciences. Newton's Opticks provided the basic paradigm for research in optics in the 18th century. Newton assumed that light was material corpuscles. The fact that most scientists accepted the paradigm had a profound influence on their research strategies. Unlike early wave theorists, they began to search for evidence that light particles exerted a pressure by impinging on solid bodies. Their assumptions had little if any direct effect on humanity as a whole. In contrast, if social scientists

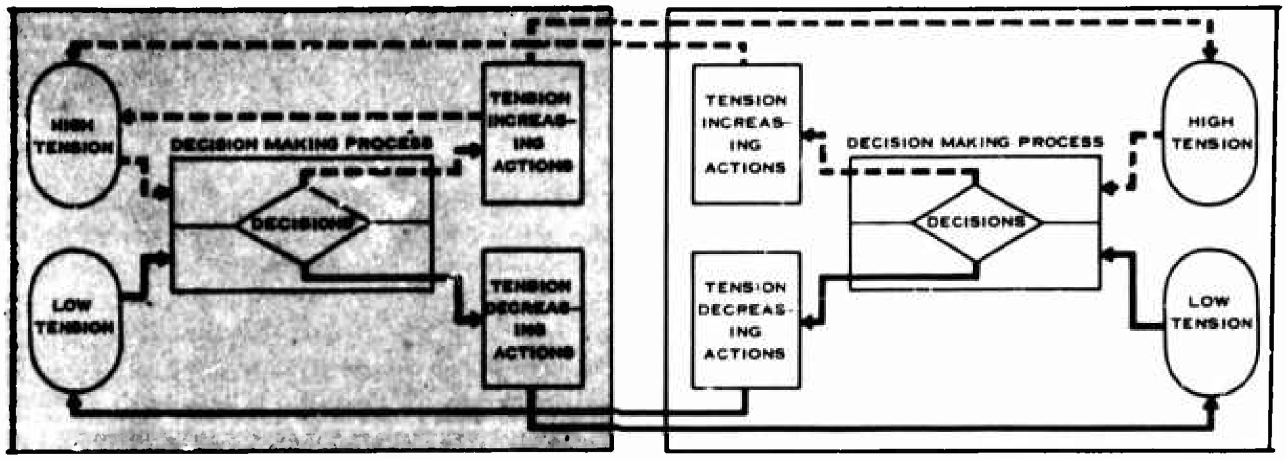

Figure 1. Model of an analog model. Schematic illustration of some of the features of Osgood's GRIT (see text).

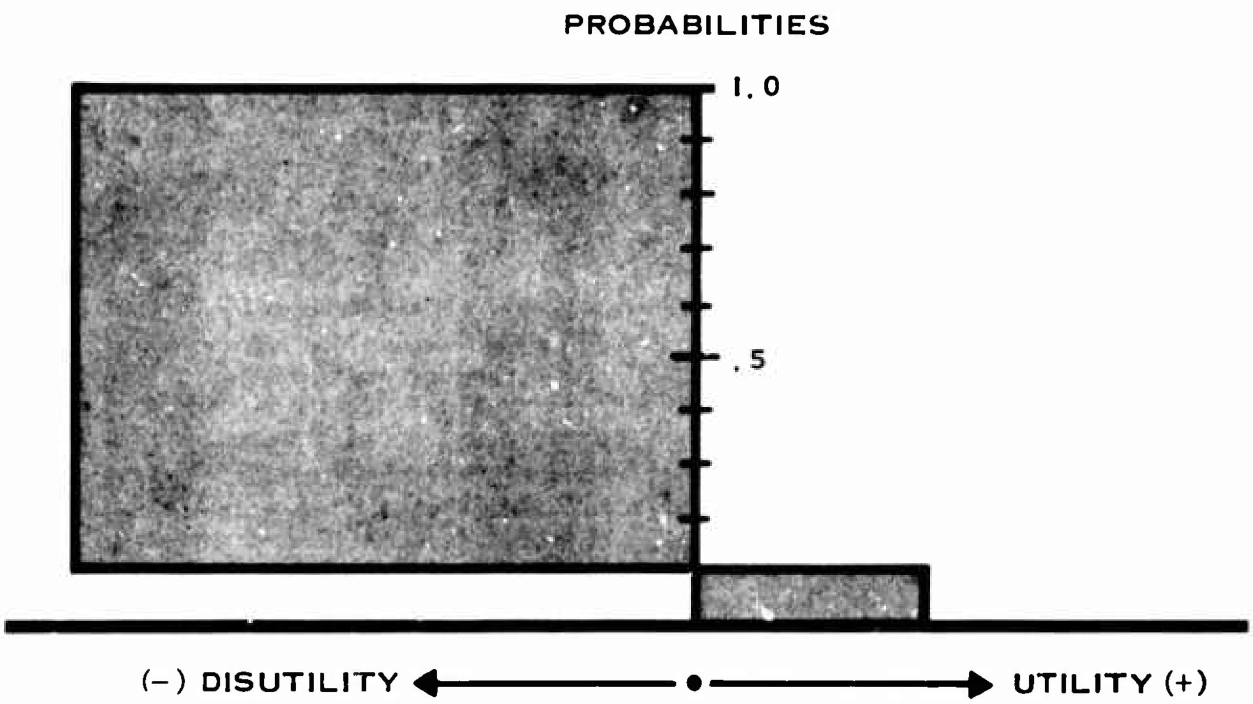

Figure 2. Deteree's estimated outcomes. Utility and probability of success are both low; disutility and probability of failure are both high. Rational deterree does not attack.

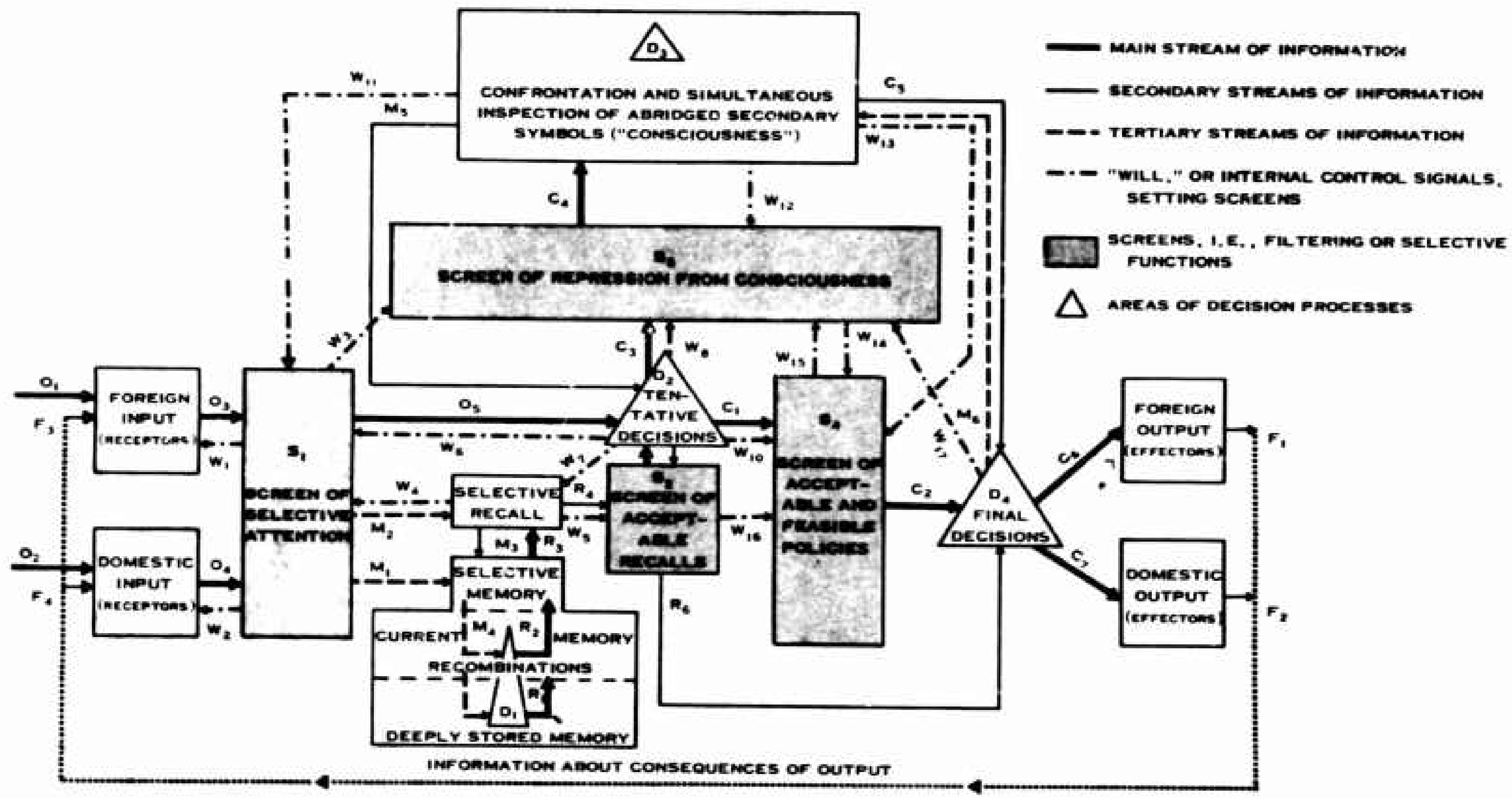

Figure 3. A crude model: a functional diagram of information flow in foreign policy decisions.

were to accept and actively propose Osgood's model of the international influence process, the consequences would extend far beyond the bounds of our laboratories. When and if psychologists agree to do this, they must bear in mind that the name of the game is no longer psychology, or even science, but international diplomacy--an exceedingly complex and specialized game in which the stakes are unbelievably high.

In defense of the promotion of models developed by psychologists, it is only fair to point out that we are, unfortunately, living in a world in which many men will admit no bounds to their spheres of competence. All around us are men willing to make the most blatant and unjustifiable generalizations about human behavior in support of their prejudices or preferred strategies of action. The conflict for the social scientist is clear. If he adheres to the rigorous canons of science, his voice may never be heard in the land. If he speaks out as a social scientist, he will be criticized (generally by his own colleagues) for his lack of rigor. At the heart of the matter is the question of purpose. A large part of our research has been directed at isolating fundamental laws of animal behavior; our horizon may well have been too narrow. If we are to speak with authority on the larger issues which mankind faces, and are to be taken at our word, it may be necessary for us to define our objectives more broadly and utilize techniques which have greater face validity.

ENVIRONMENTAL OR OPERATIONAL SIMULATION

A greater degree of face validity is achieved by stressing the simulation of content. Any international political situation may be characterized in terms of formal structure, content, or psychological essentials. Game theory stresses formal structure. Empirical research in the area of bargaining and negotiation has emphasized psychological essentials. Environmental or operational simulation stresses content.

"Model" and "simulation" are both extremely broad and inclusive terms having in common the notion of an abstract representation of some object of interest. They appear to differ primarily in having a static or a dynamic connotation. We think of models as static, whether they be iconic, symbolic, or analog. When the model is put into motion so that the effects of changes can be observed, the term "simulation" seems to me more appropriate. Thus, there are stochastic models, which are essentially a set of assumptions about how probabilities are affected by some clearly recognizable time-ordered sequence of events. There are also stochastic simulations which "set the model in motion" and enable the experimenter to compare theoretically predicted outcomes with observed outcomes. Such simulations may use digital computers or they may be done manually--but they amount to test runs of models under conditions which are determined by the play of emergent events.

The kind of simulation which bears most directly on the international influence process is environmental simulation--sometimes called operational simulation. Environmental simulation seeks to preserve rather than reduce the complexity of the environment. The experimenter tries to maintain the richness and variety of the environment and to allow human participants to respond to a situation resembling as nearly as possible "real life." Both the more traditional social-psychological experiment and environmental simulation involve measuring human actions--one in an abstract environment which bears little resemblance to the real-life situation, the other in a more complete replica of its real-life counterpart.

The origin of modern environmental simulations using digital computers can be traced back to at least the 17th Century and the development of early war games. Even today, some of the most critical political-military simulations, the so-called JCS Politico-Military Desk Games, do not require computers. These "games" are actually role-playing situations in which individual players represent governments or factions within governments (McDonald, 1964). Probably best known in academic circles is the Inter-Nation Simulation identified primarily with Harold Guetzkow (1959) and his students, and used to study such problems as Osgood's Graduated and Reciprocated Initiative in Tension-reduction strategy (GRIT) (Crow, 1963) and some effects of the spread of nuclear weapons technology (Brody, 1963). The description of a complex and interesting simulation of this type has only recently become available in unclassified literature (Abt, 1964). TEMPER is a man-machine game which is global in scope and permits up to 39 players.

These simulations are generally expensive to design and develop. Individual game runs often require large numbers of subjects--frequently subjects who have had prior specialized training--and the replications necessary to obtain the customary estimates of error variance are difficult and costly. Perhaps more germane to the present discussion, experiments using environmental simulation are as a rule conducted not to derive basic laws of international behavior or to test formal theory, but rather to produce specific phenomena under relatively controlled conditions and to intervene in the process and observe effects. Whether the results can be extrapolated to the real world remains arguable. As a minimum, we can assume that simulations sufficiently representative of the real world will produce useful insights and add support to (or refute) arguments of an informal and less structured nature.

The emotional overtones which always characterize international crises can seldom be simulated in the laboratory. A significant aspect of reality is thus virtually always missing from the environment of the simulated decision maker. Consider the startling results of a study reported by Shure, Rogers, and Meeker (1963). The operating environment of a SAGE battle staff responsible for the air defense of a sector of the United States was simulated in the laboratory. Four three-man teams of Air Force ROTC students (or specialists in air defense) faced various decision situations. One situation involved the choice of surrendering or continuing to fight after apparent defeat. With their sector in ruins

and information from the simulated Office of Civilian Defense indicating that Washington, D. C., SAC, ADC headquarters, and many of the larger metropolitan areas and military targets had been destroyed, all four crews decided to continue fighting. When one crew was advised that other cities might be spared if they made a different decision, the crew still elected to go on resisting. Now, many factors may account for this dedication on the part of the experimental subjects, and the authors of the report discuss several possible explanations including discipline, lack of humanitarian values, and cognitive dissonance. A more compelling explanation may lie in a defect which characterizes all simulations of this kind--their inability to capture the emotional overtones of the situation simulated.

GENERALIZING FROM TRADITIONAL RESEARCH

Presumably, the vast body of literature and data collected by social scientists over the past several decades also provides valuable insights regarding the international influence process. Use of such data for this purpose requires, first, the assumption that it is possible to generalize from the data of individual behavior to the behavior of nations. Decisions in international relations are, after all, made by individuals presumed to be subject to common psychological laws or principles. National decisions are made in the context of complex organizational structures characterized by internal conflict, inertia, and countless constraints on individual decision makers. Behind the formal organizational structure, available for convenient reference in government manuals, lurks an informal structure with no tidy levels of responsibility or clear-cut lines of communication. Decisions affecting a nation's destiny are made daily by numberless individuals acting, reacting, or failing to act.

Second, a large part of the data of psychology comes from two highly select populations, the college sophomore and the albino rat. Generalizing from animal studies to international relations presents formidable problems. With respect to the use of sophomores, Boguslaw, Glick, and I have recently collected evidence (1964) which indicates that for certain complex socioeconomic decisions, college students may behave very differently from mature, experienced scientists and administrators. Third, a characteristic of a controlled psychological experiment is the abstracting away of complexity. Special highly artificial environments are required to elicit some of the perceptual and other psychological phenomena which have provided the basis for generalizations about the international influence process. Unfortunately, interaction between political, social, and psychological variables is so frequent as to open to question the usefulness of this approach for extrapolating to real life.

Nevertheless, psychologists have generalized from such abstract situations to complex political problems, and have extrapolated from the

individual psychology of the laboratory to the world of international politics. Charles Osgood has made extensive use of perceptual studies. Ross Stagner (1961), Urie Bronfenbrenner (1961), and Tom Milburn (1961) have found it useful to extrapolate from the data of individual psychology to the behavior of larger social systems. And I have done it (Davis, 1963). Indeed I suspect that a truly exhaustive list would include a very large number of psychologists.

A special case of generalizing from traditional research is the rapidly expanding use of mixed-motive games for the collection of empirical data about how humans behave in negotiating and bargaining situations (Meeker, Shure, and Moore, 1964). The prisoner's dilemma is particularly useful for such studies and a number of variants of this game have been described by Pilisuk and Rapoport (1964).

GAME THEORETIC

In the present discussion, it will be useful to distinguish two broad categories of games: the so-called zero-sum game and the non-zero-sum game. Zero-sum games are competitive. One player's gain is another's loss. Cooperation will always result in one player's having a smaller payoff than he could have had without cooperation. Although to some this penalty for cooperation may appear to be so unrealistic a restriction as to completely eliminate it as a rational tool for the analysis of real-life diplomatic situations, there are those who apparently believe that contemporary military and diplomatic policy is, in fact, one vast game in which gains and losses do sum to zero. Mutual accommodation and the possibility of unilateral gain through cooperation are frequently deplored by those who see the world in these terms; total victory is extolled. In the zero-sum game, many of the most obvious features of international political bargaining and problem-solving--bluffs, threats, promises, and similar psychological factors--are completely irrelevant. Indeed, the zero-sum game is in the domain of the strategy of pure conflict. In this domain there is no need for psychology, for the players are assumed to be perfectly rational and motivated by greed.

Clearly, there are many situations in international negotiation in which one player's gain is not another's loss. Furthermore, both parties to a negotiation may, under some circumstances, gain by cooperation. Games which introduce these possibilities are called non-zero-sum. The mixed-motive game is a non-zero-sum game which permits both competition and cooperation to occur. Unlike the zero-sum game, the mixed-motive game involves at least tacit communication between players, and the outcome depends upon the social interactions of the participants. Game theory as it relates to the zero-sum game treats the players as rational automatons; and since the criteria for their behavior are explicitly specified, their decisions can be deduced within the framework of the theory. The mixed-motive game, on the other hand, introduces great uncertainty about the

player, his value system, and his strategy. The mixed-motive game, in short, reintroduces psychology--but in so doing, as one might suspect, destroys the possibility of deriving a normative theory by analytic means. The study of mixed-motive games is therefore largely an empirical matter (Schelling, 1960).

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Before summarizing my conclusions regarding the utility of these diverse approaches to the international influence process, I would like to pause and examine the real world. Decisions affecting the international influence process are commonly made in the context of a dynamic and complex environment. Frequently, the most critical situation involving the effort to influence the opponent, or even allies, is one-of-a-kind and requires a unique solution. Action-relevant states of the system of international relations during an emergency such as the Cuban crisis cannot be specified or predicted in advance. Instead, the situation is emergent (Boguslaw, 1961). In this sense, the real world frequently takes on the character of a problem-solving situation rather than a highly structured bargaining and negotiation situation[1]. Further, foreign policy does not reflect a single will, intent, or purpose. Instead, it is the melding of the hopes and aspirations, the motives and objectives of uncounted individuals, converging--by processes only half-understood--on a few men who act or react or fail to act and thereby hurtle us to the brink of war or jerk us back to the sanctuary of an uneasy peace. To the extent that our destiny is determined by individuals, as Simon (1957) has observed, these individuals construct their own simplified models of reality and behave rationally with respect to the model, even though "such behavior is not even approximately optimal with respect to the world."

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[1] One aspect of the international influence process which appears to have been neglected by those who have emphasized the game theoretic approach, including those who have stressed the mixed-motive game, is problem-solving. Because economists have done a great deal of original work in this area, homo economicus rather than man as a problem-solver has been emphasized. To psychologists who followed the Cuban crisis closely, the problem-solving aspects stood out in bold relief. The effort to discover a satisfactory solution to the inspection problem, which included a number of interesting suggestions such as the proposed use of the United Nations and the Red Cross nicely illustrates the problem-solving dimensions of the crisis. Almost daily, exploratory suggestions (and their rejection) by the U.S., the U.S.S.R., the U.N., and other nations created a dynamic and emergent environment as well. The formally structured aspects of classical bargaining were all but absent.

Game theory, designed to deal with highly structured rather than emergent situations, certainly is not directly applicable to the kind of world I have just described. We cannot hope to substitute our models of reality for the decision maker's personal model; nor is it obvious that we should try--since our models also are incomplete.

The problem as I see it is not to provide an invariant prescription for the ills of the world, but to educate the decision maker to its complexity. We ought not to insist that decision makers adopt our model of reality, but that they enrich their models by taking account of factors which we believe to be relevant. In this sense, the task is not to tell the decision maker what he ought to do, that is, to formulate policy, but rather to educate him to an aspect of reality of which he may be unaware. The data from individual and social psychology are surely applicable in some way; but the transform equations are unknown, and we should not presume to know them. What we should aim to do with the tools and techniques (including simulation) and data at hand is to help those who affect the decision making process to make their own models of reality more complete.

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CHAPTER 24

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VARIABLES OF DETERRENCE

American psychologists are self-consciously critical of the narrowness of the data base on which most social psychological propositions are founded. American economists, political scientists, and philosophers are at least as parochial as psychologists, but they do not appear to be as aware of the fact. This lack of awareness has not prevented them, economists in particular, from developing most sophisticated models. Their models have not always been as empirical as the most objective psychological micro-models--thence the role of ideology in much economic philosophy--but they are complex, possess a fair amount of construct validity, and are well accepted. As befits the practitioners of an older discipline, economists have more prestige than other social scientists, and their aid is more often sought by policy makers. It is widely assumed that the major factors determining the actions of nations are economic and political, that all nations see economic or political loss as aversive and either sort of gain as attractive. The first American strategies of deterrence, and so their major attributes, were formulated and articulated largely by men trained basically in economics and philosophy. True, these architects are very competent men, but their products have been unself-consciously American in the goals they ascribed to our adversaries and their emphasis on predictions based upon rational models of men. The popularity of game theory lies in the fact that it predicts the behavior of the other as long as the other is rational.

William Kaufmann, the first strategist to emphasize the importance of credibility for deterrence, was initially trained as a political scientist but could reasonably be described as a political economist. The other major members of the early RAND triumvirate, Andrew Marshall, an economist, and Albert Wohlstetter, a philosopher of science, contributed more than anyone else in this country to the early thinking in these areas and therefore to much of our present thinking and policy. Their basic concepts appeared in the writings of John F. Kennedy several years before he was elected to the Presidency and have been featured parts of McNamara doctrine.

The inventor of the idea that tacit bargaining is applicable both to strategic and to limited conflicts is also an economist, Thomas C. Schelling. Criticism of the zero-sum game as an analytical tool with limitations and early statements of the advantages of the non-zero-sum game as an analog of wars, especially limited wars, derived primarily from his thinking. In the

interdependent world created by man and his knowledge of the atom, Schelling (1958) sees conflicts as inextricably cooperative affairs as well as competitive struggles where continuous inter-party communication should therefore prove a must. Another economist, Daniel Ellsberg, has contributed to thinking about the nature of threat of loss. Dr. Ellsberg's early concepts of threat and of response to threat are remarkable to psychologists because they are so affect-free. He articulately employs subjective probability to write of threat as might an accountant (1961).

The "rationality" of the economist is, unfortunately, a construct which is seldom operationalized. Its criteria are uncertain and vague. Rational behavior is goal-oriented (and goal-consistent) behavior whether goals be those of individuals, groups, or nations--or the at least partially shared goals of many interperson, inter-group, or inter-nation relationships. Criteria for the achievement of rational goals through rational procedures do not exist. To limit the application of the concept a la Adam Smith to the long-term selfishness (even enlightened selfishness) of individuals would seem archaic as well as vague.

Psychologists see adaptive or competent behavior as such only in the environmental setting--in the context in which it occurs. Social psychologists looking at influence processes in international affairs and at deterrence as a particular example of mutual influence (Milburn, 1963) have emphasized the importance of situation, culture, ideology, and organizational structure as determinants both of our more or less affect-loaded perceptions of the motivations and intents of others and of others' characteristic responses.

It is likely that situations, and so situational variables, do account for much variance in many laboratory and field experiments. Endler, Hunt, and Rosenstein, in a study attempting to examine separately the effects of situation and individual differences on degree of anxiousness, found that situations contributed the most variance and concluded that this finding "clearly supports the contention of social psychologists that knowing the situation is more important for predicting behavior than knowing personal idiosyncracies" (1962, p. 29). Raush, Dittman, and Taylor, studying behavior of disturbed children in various situations encountered in a residential treatment center, found that the settings were highly important in determining behavior, particularly when each child was considered individually. They emphasize the interaction between child and setting as contributing more to behavior "than the summative effects of individual differences and setting components" (1959, p. 374).

One situational dimension is that of stress-nonstress. There is ample experimental evidence that people behave differently under conditions which the experimentors define as stressful, and that behavior varies according to intensity of stress (Cowan, 1952; Torrance, 1961) as well as duration of stress (Torrance, 1961). Information input may also be considered a situational variable. People behave differently under conditions of sensory or information underload or overload. Some of these

differences have come to be rather well-known through sensory deprivation studies and such work as that of Miller (1960). Still another situational variable is that of communication structure. Leavitt (1951) demonstrated that communication patterns within experimental task groups and the positions which individuals occupied in a communication pattern affected such elements of behavior as accuracy, activity, satisfaction, emergence of a leader, and organization of the group. In another study, Leavitt and Mueller (1951) found that in one-way communication where there was no opportunity for feedback, both accuracy and confidence were impaired and hostility tended to appear.

The importance of some of these situational variables is beginning to be recognized in studies of international bargaining and conflict situations. It appears extremely difficult, for example, to assure that tacit bargains will be successfully made in situations where either party to tacit negotiating has a high drive level or is under considerable stress, because under such circumstances discrimination drops considerably. Sinologist Allen Whiting has pointed out that Chinese signaling as to what they would do when U. N. forces approached the Yalu (Whiting, 1960) was ignored by our leaders. It may be that we did not perceive some of their messages because they were filtered through New Delhi; clearly, we did not believe the ones we got. We did not consider the threat of Chinese entry credible. In the recent Cuban crises, by contrast, we signaled and watched for effects self-consciously. There was considerable redundancy, both verbal and tacit, of our intentions so that we might be more clearly understood and our adversaries not mistake what we were up to.

The Stanford Studies in International Conflict and Integration, comparing communication among protagonists in the Bosnian annexation crises of 1908-1909 with that leading up to World War I, found that in the Bosnian crisis there was relatively more clear communication and mutual perception of roles, demands, and intended behaviors than in 1914. While the Bosnian crisis dragged on for six months, it did not erupt in war.

It seems clear that signaling behavior counts in international behavior. So does feedback in determining whether our messages are getting across. Schelling (1964) has pointed out that the Soviet and United States governments signal their intentions vis-a-vis each other not only directly, but also through their defense budgets, their messages to their own people and to their allies. He hypothesizes that this indirect signaling may count for more than direct interchanges.

We have often had the unfortunate tendency to ignore the perceptions of our messages by others. Our failure to observe or to listen to the multiplicity of messages from the Chinese with respect to the meaning we communicated to them by advancing our forces to the Yalu is an example. We and our adversaries signal and get feedback; we and they listen and observe--or else we fight a war and both sides pay in blood and money for our failure to do so. To assume that the other gets our message because we intend it so is unrealistic; feedback is essential for us to be sure.

Many other psychological variables have relevance in policy matters and have often been overlooked in the models currently in vogue. For example, our emphasis in psychology upon learning theory has led us to emphasize far more than have other social scientists the centrality of the other's past experience--rather than our own memory and past experiences--in determining the meaningfulness of threats or promises that we make. Such hypotheses have been supported by the post-World War II U. S. Strategic Bombing Survey (1945) which indicated that people who had faced and lived through military operations, and particularly civilians who had lived through the experience of being bombed, responded characteristically to threats with stronger and more appropriate affect than those who had not experienced and lived through bombings. Those experienced in disaster were far more likely to respond in an adaptive fashion and less inclined to over-respond to threats. Some--but not all--surveys of behavior in other disasters support this hypothesis (Wilson, 1962). People who have lived through one disaster tend to show much more adaptive behavior in the presence of intimations of a second disaster than with the first, and to exercise avoidance or escape behavior more appropriately.

If this hypothesis has cross-cultural validity, then deterrence should have a different meaning in affect terms for the inhabitants of Russia than for inhabitants of the United States. After all, this country has not been devastated by war since the Civil War, whereas some twenty million Russians died during World War II, even though the deaths occurred over several years rather than in hours as could occur in World War III. Our threats of a strategic sort should be far more meaningful to the Soviets than theirs to us. This does not imply, of course, that we are not deterred from attacking the Soviet Union, but merely that they should respond with more affect to what a dispassionate third party would see as equivalent threats. Attempts to content analyze the strategic literatures of the two countries, using a modification of factor-analytic technique, bear out this conclusion. The Soviet literature is concerned much more with variables relating to political and economic environment and the behavior of the enemy and is much more loaded with affect than the strategic literature of the United States which is typically far more coolly analytic (O'Sullivan, 1964).

Psychologists who are decision-theory-oriented, as well as those who are learning-theory-oriented, have emphasized that in deterrence, as in other influence processes, choice is involved; so is contrast between an alternative which may be seen as a figure and an alternative which may be perceived as a ground. The latter, of course, is straight out of Gestalt psychology. It has been easy for men who are technologically inclined to assume that the effectiveness of deterrence is essentially a straight-line function of our weapon superiority. The effectiveness of deterrence might more accurately be considered a function of the nature of choices available to the deterred, a function of certain situations, and mutual rather than unilateral.

Deterrence is, of course, a concept involving considerable inference on the basis of which we decide whether a party has been deterred from doing some act which we presume otherwise he would have engaged in. Unless, before attempting to deter, we decide fairly explicitly what the criteria are for deciding whether we have succeeded, it may be extraordinarily difficult not to have any and all outcomes support our previously-held beliefs. To know that we deter, we must know the other's goals and the nature of the means that he had intended to employ had we not engaged in deterrent actions. Seldom do we know these factors with anything approaching scientific certainty. Moreover, to be sure it is our deterrent threat-demand-promise combination that inhibits his inclination toward massive violent action, we should have some idea concerning what internal forces (intra-nation or intra-bloc) may also be acting to reduce his disposition to initiate violent conflict. If these internal forces are large, they, rather than our actions, deter--in which case we have less need to behave in a fashion intended to deter. If a crisis stops or phases out, can we infer that our deterrence or some particular aspect of it has succeeded?

Neither threats nor promises of rewards are necessarily unidimensional. Neither occurs in a vacum. Our threats, for example, shift their meaning depending not only upon the perception of our words and actions by those threatened but also upon their assumptions about our intentions and the affective meanings that they associate with their assumptions. If our adversaries, whom we would deter with threats and promises, suppose us to be dangerous to them, and if they fear destruction or humiliation from us, then our threats and demands possess a devastating quality impossible otherwise. If they consider us relatively benign, then our threats and demands may perhaps usefully serve as one basis for negotiation. (Shure and Meeker, 1963). Promises of gain from adversaries one already regards with dread are themselves not credible. Unexpected threats or threats coupled with growing demands from opponents we already regard as aggressors may, even inadvertently, invite violent responses. Such threats are not readily coped with, and they imply even worse dangers yet to come.

Threats are negative incentives; they usually are coupled with demands not to act, or to stop acting in certain ways. In themselves, they of course scarcely indicate what are appropriate ways to act. Positive incentives (promises, tacit or explicit) may be similarly coupled to contingent behaviors which are more or less completely spelled out. That is, one gives A or B if the other does X and does not do Y. Whether incentives are effectively positive (as whether other incentives are appropriately negative) must be defined in response terms. For negative incentives we wish to know whether our opponent stops or desists; for positive incentives we wish to know whether our opponents act more nearly or more often in ways that we desire. Unfortunately, we seldom spell out even to ourselves the behavioral goals we have for our opponents and toward which we need to press. Of course, we must not only define these goals for ourselves; we must use them as bases for action in our dealings with our adversaries if we are to employ positive incentive successfully.

Our inventory of unknowns is not small, and the above list could be considerably expanded.

Summary. The major contributions to concepts or variables for thinking about strategic deterrence have come from social scientists other than psychologists. These excellent contributions have neglected consideration of some important and relevant aspects of deterrence, such as the effects on perception and meaning of situational variables--stress level, communication structure and feedback, the effects of past experience on adaptive behavior, and the importance of defining goals of deterrence or positive influence and criteria for meeting the goals. Psychologists can perhaps be encouraged to broaden their data bases in order eventually to provide theorists and policy makers with improved models. If we conclude that more valid insights are obtained by those closest to the data, then one major challenge facing psychology today is that of developing and using theoretically-based techniques for the study of the complex, quite real, and very practical problems and issues facing mankind.

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